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SPECIAL FEATURES

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TRANSACTIONS
of the
American Society for Steel Treating

Vol. II Cleveland, November, 1921 No. 2

RESEARCH PLANE MUST BE ELEVATED

IN THIS issue of TRANSACTIONS considerable attention is devoted to the question of research, a subject much discussed at the recent Indianapolis Convention. The various papers which were presented and the discussions that followed brought out most forcibly that the proper kind of research is absolutely essential to the welfare of all industry, for without it the wheels of progress would cease to turn. Research is a broad subject and has many phases but briefly may be divided into two classes, namely, that conducted by private organizations for their own development and that conducted by organizations grouped together for the good of the industry at large. It was around the latter type of research that the greatest attention was centered. An outstanding feature of the discussion was that up to the present time, pure research work has not been made sufficiently remunerative to attract men to that field. Many of those now engaged in that work remain solely for the love of the work. That this condition is not to advantage in the advancement of science is realized, but realized only by the organizations engaged and interested in research. Only by a campaign of education for industry as a whole can this phase of research work be elevated to the proper plane to which it belongs.

MORE NIGHT SCHOOLS ARE ESTABLISHED

AT LEAST two more night schools devoted to heat treating and metallography and sponsored by the American Society for Steel Treating have been announced for the coming winter. One is offered by the Philadelphia Chapter at Temple University and the other is to be conducted by the Worcester Chapter. The former is to be operated similarly to the highly successful school of the Chicago Chapter at Lewis Institute while the latter is arranged upon less formal lines. As demonstrated by the Chicago experiment one year ago, such schools serve a useful need and are well patronized. It is hoped that in the future other chapters of the Society will see their way clear to aid to the upbuilding of the profession by the establishment in their localities of suitable instructional facilities for the training of heat treaters and metallurgists.

Such schools ordinarily are conducted two evenings a week for a period of about 20 weeks, from two to three hours being devoted to each session. Instructors are selected from members of the chapter or selected from the members of instructional staffs of local institutions. Fees are made as low as possible, just being sufficient to cover the cost

JOHN ALEXANDER MATHEWS

of operation. These courses offer exceptional opportunities for young men to become heat treaters and for practical shop men to acquire some of the theory of modern practice without in any way interfering with their daily occupations. Shop men should be anxious to receive the teachings of experienced teachers and thus to rise to higher planes in their vocations.

DR. JOHN A. MATHEWS ELECTED TO HONORARY MEMBERSHIP IN THE SOCIETY

AT THE recent convention in Indianapolis, Dr. John Alexander Mathews, president of the Crucible Steel Co. of America, Pittsburgh, was elected an honorary member of the American Society for Steel Treating. For over 20 years Doctor Mathews has been active in investigations of iron and steel, his first being carried on at the old Sanderson works in connection with the study of permanent magnetism. At that time practically all permanent magnet steel used in this country was imported. He was the first in this country to adopt magnetic testing in conjunction with the manufacture of steel. Tungsten and chrome magnet steels were investigated thoroughly. The result was that in about five years this country stopped the importation of magnet steel and a little later began to export it to several European countries.

Simultaneously Doctor Mathews began the study of magnetic properties of miscellaneous steels and alloy products and made some efforts to correlate magnetic and physical properties as affected by analysis and heat treatment. When during the war, tungsten became so expensive and the need for high speed steel was so great that it was not profitable to make tungsten magnet steel, he was instrumental in introducing a substitute magnet steel almost equal to the former grade. In this connection, he discovered that certain alloy steels are magnetically more permanent when quenched in oil than when quenched in water, even though they are physically softer when oil quenched. This was entirely contrary to all previous ideas of permanent magnetism of steel for it had been generally considered that the hardest physical state afforded the most permanent state as regards magnetism.

It was Doctor Mathews' fortune to investigate vanadium steels at an early date and his first inquiry for ferrovanadium brought a quotation of $75 per pound, the entire supply in the country at that time consisting of about 50 pounds of contained vanadium in the form of ferro and this was in the hands of two importers. His investigations included the effect of vanadium on plain tool steel but its principal value was found in connection with high speed steel. Its introduction into this product doubled and tripled the cutting efficiency of high speed steel then on the market. Other elements have been used in additions to high speed steel but their effect has been slight and has resulted in products of limited and special application. In connection with vanadium steels, Doctor Mathews produced nickel vanadium, chrome vanadium, nickel chrome vanadium alloys and furnished samples of this material to the late Henry Souther who was then metallurgist for the Licensed Automobile Manufacturers Association. These were the first vanadium steels Mr. Souther had ever seen and the results of his tests constituted the first authentic data the automotive field had in regard to vanadium steels. Doctor Mathews' investigations of these steels included shock tests which were then seldom made.

When Doctor Mathews went to the Halcomb Steel Co. in 1908, the original Heroult electric furnace first installed in this country was considered a failure and it was contemplated to abandon it. However, with the co-operation of associates, the furnace was operated successfully for the manufacture of a wide variety of products and established a new standard of quality and value in the production of alloy steels.

Doctor Mathews was born at Washington, Pa., May 20, 1872. After studying in the public schools of this place, he took the B. Sc. degree at Washington and Jefferson College and the degree of M. Sc. at the same college in 1896. He next attended Columbia University where he received the degree of Ph. D. in 1898. In 1899, he attended the Royal School of Mines, London University, London, Eng., where he took up research work under Prof. Sir William Roberts-Austin, K. C. B. His first occupation was as instructor of chemistry at Columbia University. He left the university in 1902 to become metallurgist in charge of experimental work at the Sanderson works of the Crucible Steel Co. of America, and two years later he became assistant manager, remaining there until 1908. In this year he became operating manager of the Halcomb Steel Co., Syracuse, N. Y. Later he became general manager, and in 1915 president of the company and at the same time was made president and general manager of the Syracuse Crucible Steel Co. He was elected a director and first vice president of the Crucible Steel Co. of America and was transferred December, 1919 to Pittsburgh, holding that position until November, 1920 when he was elected president of the company, which position he now holds. In the years 1900, 1905 and 1911, he accepted the honorary appointments of assay commissioner under Presidents McKinley, Roosevelt and Taft.

In recognition of the numerous technical papers and results of investigations which he had published, Doctor Mathews had conferred upon him in 1902 by Washington and Jefferson College the honorary degree of Doctor of Science. He was the first recipient of the Carnegie Gold Medal for Research from the Iron and Steel Institute of Great Britain in 1902. In addition to the American Society for Steel Treating, other technical organizations of which he is a member are: Chemists, and Engineers Clubs of New York City, American Chemical Society, American Society for Testing Materials, Iron and Steel Institute of Great Britain, and the American Electrochemical Society.

COMPANY OMITTED FROM EXHIBITORS' LIST

In preparation of the list of exhibitors at the Indianapolis Convention, Sept. 19-24, omission was made of the name of the Atlas Crucible Steel Co., Dunkirk, N. Y. This company was represented with a booth and a display of crucible tool steel, carbon tool steel and drop forgings. The company was also an exhibitor at the two previous exhibitions of the Society and is a consistent advertiser in TRANSACTIONS.

ASSISTED IN PREPARATION OF PAPER

In the paper "A Contribution to the Problem of the Influence of Mass in Heat Treatment" by E. J. Janitzky, metallurgical engineer, Illinois Steel Co., South Chicago, Ill., and appearing on page 55 of the October issue of TRANSACTIONS, credit should have been given to Harry Blumberg, assistant to Mr. Janitzky who aided in the preparation of the work. Mr. Blumberg is a metallurgist with the Illinois Steel Co.

THE UNIVERSITY AND INDUSTRY

By A. E. White

THE underlying strength of our nation is laid to our sterling belief in and support of our religious institutions and schools. It is our unwavering attachment to these two segments of our civilization that has filled us individually, and our nation as a collective body, with those high ideals which have placed America in the forerank of the countries of this world.

There may be those who claim that our churches are losing strength but such views are held by pessimists rather than optimists for the examination of the facts would indicate the grip which our religious institutions have upon us. With incomplete returns for the year 1916 there were reported 227,487 organizations and 41,926,854 members with an estimated national population of 101,882,479. Further the value of the church property of 197,807 of these organizations that same year was given as $1,676,600,582, with an estimated total national wealth that same year of well over $200,000,000,000. A dissertation on our church strength, however, is not the object of this paper. It has been developed to the extent set forth for the purpose of indicating that it still plays and gives every indication of ever continuing to play, a tremendously important part in our civilization.

Hand in hand with our churches are our school systems. During the past few years these fell into a depression at a time when all industrial activities were riding on the top of the wave of prosperity. The depression was due to two conditions. First, the boards of education, trustees and other similar governing bodies were not able to advance salaries as rapidly as industrial concerns. Those, therefore, that remained true to their trust as teachers were financially at a handicap for the high salaries and wages paid by industry caused the purchasing power of the dollar to shrink greatly. Secondly, many teachers and large numbers of prospective teachers joined the ranks of the industrial worker leaving the teaching profession either undermanned or poorly manned. The day of unattractiveness in the teaching profession is on the wane. Today our boards of education can pick and choose and we are not forced to place the training of our youth in the hands of inexperienced or incompetent teachers.

What education has suffered through the ruthless encroachments of industry during the past five years, the field of research has suffered for the past 25 or more years. The difference in the encroachment in the two fields has been purely a matter of degree. In the one case it was in the nature of a rapid poison and in the other in the nature of a slow poison.

Yet we must not censor industry too severely. Much of the trouble from the educational standpoint has been due to a type of organization not elastic enough to meet new and changing conditions with sufficient promptitude; and the trouble from the research stand point has been due to the maintenance of too close adherence to the classical viewpoint and too little appreciation of the vast industrial strides which this nation is yearly taking and the demands these strides are making on our institutions of higher education for a revised viewpoint on research.

Broadly speaking all will agree that research work should be fundamentally tied up with university activity. This being the case our differences are not on the desirability of research but rather on the conception of its

A paper presented at the Indianapolis Convention. The author, A. E. White, is director of the Department of Engineering Research, University of Michigan, Ann Arbor, Mich.

function; a conception as to whether we should make an effort to attack those phases of research which will mean greater employment and greater prosperity for the people. There are those who feel that such a conception of research is not in keeping with the best traditions of our schools. They feel that all research whether in the philosophical or in the natural sciences, should be abstract, intangible. They fear the possible corrupting effect of money upon those engaged in research, since they believe that attempts will be made to use research for the selfish benefit of a few. They hold themselves aloof from matters of an industrial character. Their training, their very life work has necessarily kept them out of contact with industry and its needs. Because of their ignorance they insist upon viewing collegiate research in the same light as it was viewed by their grandfathers. They are willing to profit by our material advances but are unwilling that our universities should have their share in furthering these advances.

To whom do we owe the developments in our steam and electric transportations? To whom do we owe the electric light, modern sanitary equipment, the automobile and the many other things which make life easier and more pleasant? Would we replace our modern Pullman or automobile with the leather strung coach, would we return to our oaken bucket in preference to our modern bath room fixtures, do we prefer candles to the electric lights? It is true that college men have had their share in these developments, but—and here is the distinction—not as graduates or as alumni doing their work in close contact with the university, but when in large measure, if not completely, divorced from the university. In general it is true that while college trained men have done much in the development of industry and engineering, the universities have, as institutions, kept somewhat aloof.

Personally, the author has no quarrel with those who believe the university should stick closely to abstract research. He, believes we should encourage in every possible way work of that type, for through it we widen our knowledge, we add to our culture and in the field of natural science we work toward laws which are at the foundations of science.

Time will not be taken in this paper to indicate the need and necessity for research work. It will be assumed that there is complete unanimity on this point. During the war just passed the necessity for research and an appreciation of the fact that we were greatly handicapped because we had not previously given it proper attention, was daily thrust upon us. We were all at such a fever heat, that much of the work undertaken did not result in returns to the extent that might have been expected from the expenditures involved. Our experience should teach us one thing if nothing else, and that is that research work cannot be conducted in such a manner as to result in the greatest service if carried out at a time of great stress.

Possibly we as a nation became too enthusiastic in this matter; particularly was this the case with certain firms for they employed almost any one who made any pretense of having ability in research and placed at the disposal of such persons vast resources. With the depression which started last fall these same firms realized that much of their industrial research under the conditions just set forth had not been productive. In consequence there was a swing of the pendulum in the opposite direction. Possibly it has gone too far. There appears to be today a more sane attitude on this proposition. Persons are sought in this work because of the ability which they are known to possess rather than because of blatant self-advertisements.

Furthermore, there seems to be a growing belief that research should

be handled through associations and groups of interests rather than by individual companies. This feeling possibly is not held in a few of our major corporations, for due to their very size they can carry on research work as advantageously as any group. Nor is it possibly true in the field of certain endeavors which seek for secrecy. Yet most industries appreciate that they have problems which are common to their competitors and that research work carried out under joint alliance would be beneficial to the industry as a whole and to them individually. It is in this latter field of research that our universities have a splendid opportunity to be of service to the industries themselves, to the field of science and to the advancement of the well-being and prosperity of the people as a whole.

In 1916 there were 574 universities, colleges and schools of technology in this country. Roughly speaking we may divide these institutions into two classes, one of which we may speak of as our endowed colleges or universities and the other of which we may speak as our state universities. Of the former there are over 59 which have an endowment of over $1,000,000, there are but ten which have an endowment exceeding $10,000,000, five with an endowment of over $20,000,000, three with an endowment of over $30,000,000 and but one namely, Harvard University, which has a greater endowment, the exact figure being given as $43,000,000. All of these sums are not available for such expenditure as the governing body of any given university may desire, for many of the donations are so presented that the uses for the income are specified. Of this money there is very little available for research work and therefore the method wherby institutions of this type may operate in this field is different than the method or methods under which our state universities may operate.

Schools and colleges supported in part by state or national funds represent a later development than those supported in whole or in part by funds from endowment. The first state university in this country was established at the University of Virginia though the university which has stood as the outstanding state university since its establishment in 1837 is the University of Michigan. This institution, for example, today has a yearly income from its mill tax of approximately $1,000,000, and an income from tuition fees of approximately $1,000,000. The income from the mill tax represents an endowment of 5 per cent of $60,000,000, which sum is in excess of that of any of our endowed universities. Further, the state legislature at its 1921 session granted $4,800,000 for the erection of new buildings and the procurement of increased facilities, with a promise that additional sums would be granted for such further legitimate needs as might develop. The statement of the conditions at the University of Michigan does not necessarily mean that the operating income of the university is in excess of that of some of our larger endowed colleges and universities for in some of these latter schools the gross operating income is made to equal that or exceed than in many of our state universities through higher tuition and matriculation fees. There is every attempt on the part of our state universities, however, to keep these fees as low as possible for it is one of the primary objects and purposes of our state universities to provide higher education at as nominal a cost as possible.

The favorable conditions which exist at the University of Michigan can be or are equaled in many neighboring states. In fact, were the matter of state wealth a criterion of university strength the conditions just set forth as exisiting at the University of Michigan could be surpassed in the states of New York, Pennsylvania, Ohio, and Illinois and would be closely ap-

proached by California, Iowa, Massachusetts, Minnesota, Missouri, New Jersey, Texas and Indiana.

These state universities, because they are in large measure supported by funds from the people, owe to industry and to agriculture a greater responsibility than is the case with our endowed institutions. With the present funds available they cannot enter the field of research to the extent they would like. Additional sums must be procured. There are set forth six plans for this work. Some of these are applicable to our endowed institutions although such is not the case with all of them.

I.—Income from Individual Problems

This plan would require each individual firm or group of interests to pay the larger share of the cost of each piece of work undertaken. This is a procedure which is in operation at Mellon Institute and is fundamentally the procedure under which the Massachusetts Institute of Technology now operates. In both of these institutions, however, special privileges are granted the donors of the funds, such as deferred publication, opportunities to patent and other matters of a similar character.

There are those who feel that state universities should operate under this plan although there is considerable question relative to matters of deferred publication and the granting of patents. It must be appreciated that state universities are the people's universities and no special privileges should be granted which will be unfair to the people of the state or give any interests in the state undue and unfair advantages. Yet, one must also realize that through the acceptance of funds to cover the larger portion of the cost of an investigation the university owes the donors of such funds a certain responsibility in the matter of protection from the inroads of unfair competition. Succinctly stated the question is this, how can the donor of funds for research work be protected from unfair competition and at the same time how can the state universities as the recipient of such funds protect the people?

It is the writer's personal feeling, and in this matter he speaks as a private individual and not as director of the department of engineering research at the University of Michigan, that no patents resulting from the research activity should be granted the donors of funds. It is his belief, however, that patents should be granted and taken out in the name of the university or in the name of some corporation indirectly connected with the university so that the work be protected from fraudulent patenting.

The matter of deferred publication presents, it is believed, quite a different angle. In the first place no publication should be authorized until after the results are checked and thought over sufficiently to procure the minimum possibility of error. It is believed that at least one year should elapse between the time of the completion of the work and its publication. In the meantime the report should be examined by a competent technical committee and with its acceptance of the technical data contained, it should be passed to a committee from the university for approval relative to university policies. Proper survey by these two committees will require well toward a year.

Secondly, the university by the acceptance of funds for investigational purposes is doubly obligated. It must protect and safeguard the people's interests. It must also prevent the use of the information procured by unscrupulous competitors of the donor until such time as the donor is in a position to protect and defend his interests properly. Though it would be im-

proper for a state university to grant exclusive use of information through the protection afforded by a patent, yet the donor should be protected to some degree and the method recommended is the withholding from publication of the data procured until the lapse of one or more years. In the name of the public we must be careful not to step over backwards. If we accept money from a donor we owe him a certain obligation. Further new processes unless protected in some slight measure are not enthusiastically received by the business world. Failure to appreciate the responsibility incurred through the acceptance of a donor's funds because of the denial of deferred publication may result in no research being conducted on a given problem. This same problem, if solved and the results placed at the disposal and use of the people, might redound to their great benefit and service.

Though privately endowed universities may grant special privileges our state universities, if engaged in research for private interests who in large measure pay for the work, should only do so under such conditions that the people's as well as the donor's interests are completely safeguarded.

II.—Income from State

This is a method which is applicable only to our state universities. It is the one employed by the University of Illinois. It has certain advantages in that it insures continuity of income. The main disadvantage is that it does not procure close contact between the university and industry. These latter are only vitally interested when financially concerned. The problems attacked, therefore, though valuable and distinctive, lack that close relation to industrial needs to make them of maximum service. For this reason this method of financing research work is not enthusiastically endorsed.

III.—Formation of Association

The third plan calls for an organization in each state of chambers of manufacturers with annual dues based either upon capitalization or number of employes. This plan is not recommended for there would be no fair division of the service which a research department might render. Certain firms or interests would procure great service, whereas other firms because of the failure on their part to properly present their needs or the failure on the part of the university to appreciate these needs would be neglected. As a matter of fact in the State of Michigan we have close contact with the manufacturers through the Michigan Manufacturers' Association. The contact involves no obligation on the part of either the University of Michigan or the Michigan Manufacturers' Association though because of the contact there is a community of interests and a channel for the interchange of service.

IV.—Joint Financing
Industries Provide the Endowment—State the Building

A further plan applicable only to state universities is the one wherein the industries provide the endowment and the state the building. This arrangement would bring home to the manufacturers their interest in the department because of their contributions and it would lead toward their taking an interest in order to receive some return from the contribution made. It is not whole-heartedly endorsed as it offers no vehicle for providing definite interest on the part of the industries in the given problems on which work is in progress. Attempts in this connection can be made through an agreement to work on only such problems as meet with the approval of such proper committees as may be appointed, but the work leading to the solution

of these problems would be watched by the manufacturers with much more keenness if they were vitally concerned with their financing.

V.—Joint Financing

Industries Provide Buildings—State the Endowment

This method is also applicable only to state universities. It is open to the same criticism as applies to the preceding plan. For this reason, therefore, it will not be developed at further length.

VI.—Industries Provide Building and Endowment

This is a plan open to our endowed universities and to our state universities. It is a plan under which our privately endowed universities could probably operate. As a matter of fact the first plan and this one are probably the only ones under which they can operate. For state universities it is not recommended to the same extent as the first plan, namely, that whereby the state provides building facilities though the cost for each individual problem be borne by the interest or interests requesting the investigation.

At the present writing there are four institutions which have undertaken definite forward steps in engineering research. Mellon Institute at the University of Pittsburgh has been built through private gifts and private interests pay for the researches undertaken. It is operating substantially under the sixth plan. The Massachusetts Institute of Technology operates under a similar arrangement though the building in which the research work is done was not purposely erected for research work so much as it was for instructional work and the funds which have been received by the institute were not paid with the definite understanding that a given problem would be attacked. Rather they were paid by firms with the understanding that they would be privileged to bring such research problems to the institute as they might desire provided they would still further agree to pay the specific costs involved. This plan is substantially the sixth one named though it is set forth along with that of the Mellon Institute because of its slight dissimilarity. At the University of Illinois we have a department of research which is supported exclusively by state funds. This is essentially the second plan that was mentioned. At the University of Michigan we have in process of development a plan whereby the state provides buildings, library facilities and the use of such testing equipments as it has in its various laboratories. The interests requesting the work pay for the services of those engaged and for such special apparatus as may be required.

It is incumbent upon all universities to keep forcefully before the public the facilities which they possess for research. We must also fully appreciate that the further advancement of universities depends in large measure upon the research facilities made available to the staff. Research at our institutions of learning has not advanced in the same degree or in the same proportion as has research in our private industries. If there is any course which will result in the killing of the goose which lays the golden egg this will be the course to follow. Research must be encouraged and research facilities must be made available for our faculties in order that (1) the teachers may be content to remain connected with universities and thus give of themselves and their inspiration to the student body, (2) in order that there may be suitable training schools for the young men who are to go out into the field of research for private interests, and (3) in order that the universities may keep abreast of the times and do their share in the advancement of our civilization.

THE GOVERNMENT LABORATORY AND INDUSTRIAL RESEARCH

By George K. Burgess

MUCH has been written recently concerning the various aspects of industrial research and especially the role that is being played, or should be played, by each of the various types of organization, such as the engineering society, the university, the independent research organization, the government, and industry itself; and the discussion often has centered about the co-operative aspects of research as between two or more of these parties.

It is generally conceded by representatives of industry that industrial research has for its immediate object the increase of profits, and consequently the brunt of the cost of maintenance should be borne by industry, which should also itself carry out at least the greater part of the research work required. There is a very great divergence of appreciation of the need and value of research in the various industries, and the practices and methods also vary greatly. It is also generally conceded that the role of the university is to train men and increase our store of knowledge; many think useful co-operative arrangements in research may be made between the university and industry, and many illustrations are available.

It is not the purpose of this paper to go into a philosophical or academic discussion of what part the goverment laboratory should play on the stage of industrial research but rather, accepting the fact that tendencies as they are, to state briefly what two of the government bureaus are trying to do to encourage and help industry through research in science, engineering and technology.

It has been well said: "All research is in the public interest, and that from the public viewpoint the sole difference between abstract and applied science is one of degree and not of fact; that the important point is increased research activity irrespective of where or by what means it is carried on." If, therefore, the public has an interest in and derives benefit from industrial scientific research, it is both fitting and fair for the public, through the agency of the government laboratories, to both participate in and help support such research.

It also follows that there should be established and maintained the closest relations between the representatives of industry on the one hand and of the government laboratories on the other. This intimate contact evidently should not be limited to scientific and technical staffs of the industrial and government laboratories, but should embrace also the directors of policy in industry and government. There is another and most important characteristic of the government laboratory in its relation to this question of industrial research, one that has been often mentioned, namely the desirability in many cases of having the work done in whole or in part by an impartial body representing the public and on whose results will be impressed the stamp of authority; as in cases in which if one or the other party, as producer and consumer, either alone or together published the results, they would not carry the desired weight, however well executed.

Again, one should not lose sight of the fact that our government is

A paper presented at the Indianapolis Convention. The author, George K. Burgess, is chief of the Division of Metallurgy, Bureau of Standards, Washington.

the largest business organization in the country, therefore, the most important buyer and also maintains several types of industrial or manufacturing plant of a highly technical nature. So the government itself, in the conduct of its business, is a party vitally interested in the progress of industrial research, economies in buying, and standardization of products. The results obtained in its laboratories on its own problems are freely given to industry. The role of the Bureau of Standards has been pre-eminent in research for the government and many of its activities in the field of industrial research have been started for the purpose of meeting government needs for information relating to improvements in manufacturing processes, standardization and the formulation of specifications. As illustrations, may be cited the investigations relating to cement, concrete, paper, leather, rubber and textiles, for which small manufacturing plants have been installed.

It is often maintained that there are three essential steps in many branches of industrial research, particularly as related to new processes. First, the laboratory investigation; second, the development on a small manufacturing scale; and third, full scale production. All of these require experimentation. The government bureau may be and often is associated with all three of these stages.

What now do we find to be the relation of the government laboratory to the industries of the country? We may perhaps best approach the subject by asking of what aid can the government laboratory be to the American Society for Steel Treating, to its members individually and to the industries it represents? There are two government bureaus the work of which is most nearly related to the scope of interests covered by this Society, namely, the Bureau of Mines, Bureau of Standards. Each of these bureaus is vitally concerned with promoting the welfare of the nation in matters relating to their respective fields. They may be considered as great technical, service bureaus to which the engineering, scientific and technical interests of the country may apply for help in solving many of the underlying problems of general interest in mining, technology, engineering, physical and chemical science, and in standardization, on all of which progress in industry is based.

From the viewpoint of co-operation with industry, how do these two institutions function with respect to industrial research, which we may define as research with an avowed utilitarian motive? Let us consider first the Bureau of Mines. In the annual report of the director for the year ending June 30, 1920, appears this statement:

"During the past few years the bureau has been building up investigative work with outside co-operating agencies in a manner unique among federal bureaus. The detailed agreements entered into differ among themselves, but the fundamentals are these:

"1. Some state, or university, private or semiprivate organization, has problems in mining or metallurgy the solution of which would benefit itself and the public.

"2. These outside agencies agree to pay part or all of the cost, both in personnel and materials, of the investigation, which is to be carried on under the direction of, and according to the methods of the Bureau of Mines.

"3. The Bureau of Mines retains the right to make public and print the results of all such investigations.

"So successful has this method of solving problems been that at

present the bureau has co-operative agreements with state agencies in 11 states, with 12 different universities, and with 19 private and semi-private agencies. And the total amount of money being spent by the outside agencies on these co-operative agreements, mostly under the direction of the bureau, has amounted to approximately half a million dollars during the present fiscal year. In addition, a number of representative concerns in leading mining and metallurgical industries have appropriated money to be spent under the direction of the Bureau of Mines in production of educational motion pictures illustrating various mining and metallurgical industries. The bureau has found that these films are in great demand by the public, and that they have materially assisted the wide dissemination of information concerning the industries."

As in the case of agriculture, the Mining Industry is scattered over a wide geographical area and the problems to be solved are often local; therefore it was but natural for the Bureau of Mines to follow the practice of the Department of Agriculture in establishing experiment stations at suitably located points for the study of problems relating to the mining industry.

The Bureau of Mines is also charged with the government work on fuels—a subject of no little interest to the membership of this Society—which include, of course, coal and petroleum products of widely diversified types and situated in many areas. In its study of fuel problems, the Bureau of Mines has carried on both the field and station type of investigation but has also been able to concentrate in one or more central laboratories much of its fundamental research work.

In problems relating to process metallurgy, such as the recovering of the various metals from their ores, much the same procedure has of necessity been followed as for the mining operations, namely, work at outlying stations. In both mining and metallurgical investigations it is the custom to co-operate on an intimate and intensive scale with existing industrial plants, to the great benefit in the increase of our knowledge and improvement of the processes concerned, to say nothing of the evident economies of such methods of co-operative investigation. With the experience gained by this bureau in successfully overcoming the difficulties in one region available for new problems as they arise elsewhere, there is evidently also elimination of much wasted effort in trying out a new or metallurgical process.

In its investigations relating to mineral technology and elimination of waste in metallurgical operations, this bureau is doing much of direct interest to this Society, such as smoke and fume abatement, health conditions in shops, furnace design and operation, metallurgical refractories, and the making of alloy steels, and many others, the consideration of which here would take us far afield.

Turning now to the Bureau of Standards, we may note certain differences in methods and procedure as compared with the Bureau of Mines. We have seen how the latter bureau maintains a large number of widely scattered units or stations. In contrast to this decentralized practice, the Bureau of Standards has practically all its work concentrated in a group of laboratories at Washington although it has maintained an important station at Pittsburgh mainly for engineering work on structural materials which station, however, is being moved to Wash-

ington. There are also a few small detached stations for cement and chemical testing.

Again, the Bureau of Standards has followed less generally than the Bureau of Mines the practice of entering into formal co-operative agreements with states and other public or private bodies. We have usually adopted the less formal but nevertheless effective practice, in our relations with industry, of orienting and organizing our work through the instrumentality of committees representing industry.

It has been said committees do no work and therefore are unnecessary, but a moment's consideration will show that in many ways a well organized committee is most valuable, if not indispensible, in laying down principles and suggesting policies, resulting from the united experience of all its members. The Bureau of Standards finds in many lines of its work relating to industrial research that the committee method of outlining the problem is the only feasible one. There is established a mutual confidence among all interested parties so essential in attaining the maximum output with minimum risk of misdirected effort.

As a text defining the bureau's relation to industry, let us quote again from A. W. Berresford in his presidential address before the American Institute of Electrical Engineers:

"I conceive it to be the prime duty of the industry, first, to agree on what shall be the scope of the bureau; second, to educate the bureau in its conditions; and third, by demanding that its interests be heeded, to secure the adequate support of the bureau."

At the outset, it may be laid down as axiomatic that the director of the bureau has never considered undertaking any problem in research relating to industry without first consulting representatives of that industry, either as a group through some organized body speaking for the industry or by consulting with men of authority in the industry. Many are the illustrations of this practice; for example, there has been for years a committee appointed by various bodies interested in nonferrous metals, known as the "Committee Advisory to the Bureau of Standards on Nonferrous Metals", or for short, the nonferrous committee, which meets at the bureau twice a year. All the work on this subject is gone over before and during its execution, so that the nonferrous metal investigations of the bureau have not only the endorsement of the industry but the industry itself formulates the program. If progress in this domain has been less rapid and extensive than we should like, may we then say that, although the first two of Mr. Berresford's conditions have been met, the third is lacking?

The work on railroad materials has less formally been largely mapped out as a result of meetings of representative railroad groups held at the bureau. Sometimes a specific problem that appeals to the bureau may be presented by some railroad together with a manufacturer; such was our work on rails from different ingot types, and the investigation now being conducted on titanium treated rails; or again a manufacturer's association as that of chilled iron car wheels may ask the bureau to co-operate in carrying out an investigation on thermal stresses in chilled iron car wheels as related to design and braking; or it may be an unorganized group, as that of the steel wheel manufacturers, asking for and getting a similar investigation. Nor should there be forgotten the bureau's activities in the realm of engineering materials in its relation to the numerous committees of the American Society for Test-

ing Materials, which committees are fairly representative of both the consuming and producing elements of their respective industries and represent as well the engineering public. I suppose the list of direct or implied requests for work by this engineering body alone would reach the size of a substantial volume.

Whether he realizes it or not, every person in this country is vitally concerned in the limitations set for sulphur and phosphorus content in various grades of steel. If these limits are fixed too rigidly the cost of living rises, if too loosely, the life hazard of all of us is increased. This problem was brought formally to the bureau's attention by two bodies, one representing the government, the other the engineering fraternity; or by the United States Railroad Administration and the American Society for Testing Materials. A joint committee was formed representing the government departments, the specification making bodies, and the manufacturers. The testing and research is carried out in the government laboratories at Watertown, Annapolis and Washington, and the steel is specially produced for the investigation by the manufacturers under the oversight of the committee. A unique feature of the conduct of this investigation is that there is not a two sided table with manufacturers on one side and the users on the other—but it is a round table affair with each man responsible for endorsing each stage of the program so that no member can later say, why did you not do this or that?

The bureau's investigations on electrolysis as related to public service companies and cities are being organized on a somewhat different but nevertheless highly satisfactory basis, in which all interested parties are represented and the program put up to the bureau by them.

Hardly a day passes that there is not one, sometimes several, formal or informal conferences at the bureau by groups representative of industry who are interested in having the bureau undertake problems of research fundamental to their industry, and at those conferences the work to be done is usually mapped out, at least on general lines and often in great detail.

At the present time much attention is being given to problems relating to the elimination of industrial wastes. The possibilities of progress in this field are of unlimited extent. In a sense, of course, all industrial research from which beneficial results are obtained lead inevitably to the equivalent of elimination of waste by conservation and better utilization of materials, improved quality of products, recovery of by-products, increased efficiency of performance, or discovery of new processes and products. There are, however, many instances in industry in which the waste, as such, is evident and manifestly preventable, and it is to problems dealing with these classes of waste to which I refer. As examples we may mention the enormous losses caused by corrosion, inefficient furnace operations, excess use of manganese, and other preventable losses of material and energy in steel manufacturing operations.

Another field of industrial research, and one that will grow in importance, relates to our foreign trade, particularly the specification and testing of materials for export. The establishment and maintenance of standards in this wider competitive field will require much more experimental research than might be thought necessary. In fact in the realm of standardization and specifications, as those of you know who may be familiar with some phases of this subject, it is impossible to get far in

writing a specification before you enter the unknown, and the way can be cleared only by further experimental investigation.

We might cite many other types of problem related to industrial research on which the Bureau of Standards is now working or is qualified to assist in solving in collaboration with industry, but the author trusts what has preceded has given you a better idea than you had before of the relation of the bureau to industry and the readiness at all times on its part to participate with industry in the solution of those problems of general interest coming within its scope. The same is, of course, equally true of the Bureau of Mines.

Mention should be made of one other type of activity at the bureau —still in an undeveloped state—which gives promise of being of considerable value to industry. This is the practice started about two years ago of an industry sending men to the bureau to work on problems that industry is interested in having solved and for which the equipment and atmosphere of the bureau may be particularly suited. This practice was instituted by the bureau largely in self-defense at a time when manufacturers were drawing men from the bureau in alarming numbers and it was also coincident with the reduction of the bureau's funds. We call these men research associates or assistants, and at the present time there are twenty, six of whom are working on metallurgical problems, and the others on problems relating to hollow tile, terra cotta, visibility, lime, gypsum, plasticity of fats, cement, and the constants of ammonia. There are great possibilities in the extension of this system under which men are trained as well as problems solved, and the benefits to industry are self-evident.

Much might be said of the educational advantages of the government laboratory in training men for research positions in industry. The bureaus of mines and standards often have been severely crippled by losing men to industry. It is not in general to the advantage of industry to so cripple an organization working for the benefit of industry.

It is trite to say that research, industrial or any other, is expensive, so is life insurance; but it is far more costly not to support research adequately, just as it is not to make provision for future contingencies. It has been said such government laboratories as the bureau of standards and mines are luxuries we can easily dispense with; yes, just as the farmer's seed and fertilizer can be dispensed with to his ruin. What does it cost per capita for the Bureau of Standards or the Bureau of Mines? It costs almost exactly a cent apiece for each inhabitant of this country, which if I were not a member of the staff, I would characterize as dirt cheap, the price of the tax on one 10-cent movie ticket.

The American Society for Steel Treating is concerned with many problems, some of them of great intricacy, involving not only the perfection of practice in the subject of heat treating but dependent also upon the new facts to be discovered relating to the properties of the various types of steel and the characteristics of many auxiliaries such as fuels, refractories, pyrometers, quenching media, furnace control and design; problems relating to geometry and mass of heating and cooling objects, and many others.

We, at the standards bureau, would be glad to see formed within this Society a committee advisory to the Bureau on Heat Treatment of Steel, which would enable us to keep in touch with each other so that the bureau's efforts in this field of investigation would be constantly in

harmony with the most progressive minds in the country interested in furthering progress in this subject.

Finally, the author wants to make a special plea for scientific research in industry at this time. We have been witnessing, during this period of depression, the cutting down and even entire wiping out of many research departments. How many times have we all heard the argument; in times of prosperity we have not the time and do not need research, and in hard times we cannot afford it? In my opinion, the wise board of directors is the one which stimulates research in hard times and even if it has to borrow money to do so. Competition will be keener than ever as prosperity returns and the company which has in the meantime sharpened its tools by increasing its research facilities will score in the long run. There is no greater economic waste than wrecking a going research group.

DISCUSSION OF THE RESEARCH SESSION

AT THE research session which was conducted on Friday morning of the Convention, four papers were presented dealing with various phases of the problem. Dr. H. E. Howe, chairman Division of Research Extension, National Research Council, presided at the meeting. Two papers are given in full elsewhere in this issue. Sufficient valuable discussion took place at the session to warrant publication of the stenographic notes which are in part as follows:

CHAIRMAN HOWE: It is obvious that in all periods from earliest times there have been constructive minds at work upon the problems which have presented themselves. Those men who domesticated the horse, the cow, and the dog must have compared favorably in intellect with leaders in later times. The same may be said for those who succeeded in developing domestic grains from wild flax, this work having gone on so rapidly, there is at present uncertainty as to the identity of the parent plants. The winning of metals from the earth and the adaptation of these metals to the service of man also required thinking of no mean order.

The bright spots in history may be said to be those resulting from the work of larger number of constructive minds rather than the other periods known as the dark ages. Here and there the structures which remain to this day often testify to these particularly fortunate periods in history and much of our present day progress has its roots in the inventions and discoveries made by constructive minds many years ago.

Perhaps there has been no time in history when so many constructive minds have been at work as at present. The present also offers greatest encouragement to such constructive thought. Those industries which are founded upon the sciences have made the greatest progress with the least waste of time and energy and some of the older activities which have behind them thousands of years of experience are beginning to find that even they can employ scientific and industrial research to undoubted advantage. We need only to compare the progress of the electrical sciences and arts in the last hundred years with what has been accomplished in textiles and ceramics in five or ten thousand years.

Steel treating, of course, is an excellent example of applied science and the members of the American Society for Steel Treating are to be complimented upon the progress that has been made in their art. It is obvious to all that further research is a necessity and an activity which holds out every promise of being profitable. The purpose of the present session is to encourage members of the society to further efforts and to suggest various means by which the fundamentals underlying the work can be studied, new laws established, and new principles developed by means of which the most difficult of the problems may be solved. The men who will speak at this session come from different fields of experience in research and all are known for what they have accomplished and all have very much at heart the success of any research which may be conducted by the members of the American Society for Steel Treating, individually and co-operatively.

The first speaker will be Dr. Hyde, of the General Electric Co., his headquarters being in Cleveland, and those of you who have followed the progress of illumination know that he has contributed a great deal

to it. Dr. Hyde will address this meeting on "Field Industrial Research."

Dr. E. P. Hyde, director of research, Nela Research Laboratory, Cleveland, presents a paper "Field Industrial Research." This paper will be published in the December issue of TRANSACTIONS.

CHAIRMAN HOWE: The next speaker of this symposium will be Professor Adams, chairman of the Division of Engineering of the National Research Council, and who is soon to return to Harvard University as professor of electrical engineering. He is going to speak to us on "The National Aspect of Research."

PROFESSOR ADAMS: I wish first to take exception to only one thing that Doctor Hyde has said, and that is that engineering is an art. I think perhaps he is right if he applies it to the average work of the engineer today, but it ought not to be applied to an engineer who hasn't the fundamental grounding, and the science underlying his profession must fail absolutely in solving those many problems that are presented to him. In many cases he doesn't even see the problem because he hasn't that habit of visualization and the necessary ground work and thus doesn't understand it. He need not be a scientist in the sense that Doctor Hyde mentioned.

Professor Adams reads paper and comments on it as follows:

There is one little thing with regard to fundamental engineering research, as I have called it, which I wish to read and to connect up my terminology with Doctor Hyde's, I am going to compare the two. I have called "scientific research," both the "frontier research" and the "intensive research", as the "development of the new fields opened up." I have referred to "fundamental engineering research" and to "industrial research," somewhat differently than Doctor Hyde, but I wish to make this distinction, which is important for the purpose of comparison between fundamental engineering research and industrial research. By fundamental engineering research I have in mind that great field of research work which is in large degree scientific and includes as well the determination of the properties of materials. I just have two illustrations here. We have under the Engineering Division of the National Research Council a research for the determination of fatigue in metals. That research is not aimed solely at the collection of a mass of material for giving the fatigue limits or endurance limits of materials. To do that over the whole field of all materials would be an almost endless job, but it has also, and really as the primary objective, the acquisition of a deeper knowledge in regard to the nature of the phenomenon and the relation of these fatigue or endurance limits to other more easily determined properties of material. Thus we hope to be able to predict or approximate the fatigue limits of materials that haven't been put through long and tedious tests.

Another illustration is our electrical insulation research, an almost exactly parallel research. The question of what we call dielectric losses is, in some respects, analogous to your fatigue phenomena, due to the constant alteration of stress to which almost all high tension insulation is subjected, 60 cycles per second, day in and day out.

We have also what corresponds to the impact tests, impact resistance power. The insulation is subjected to surges, certain energy behind it; these surges frequently give rise, after the first impulse, to very high frequency, much higher than the normal frequency of the circuit. So

we have phenomena that are in many respects exactly analogous to fatigue phenomena.

The distinction that I wish to make is that the fundamental engineering research deals not with the problems that are of particular interest to manufacturers—and in the industrial research I have included that research aimed at the solution of specific problems of immediate interest to the manufacturer, and in many cases involved in the development of ideas, practical or otherwise, many of which it is important from the corporation point of view to keep secret—whereas, what I have called fundamental engineering research I wish to confine strictly to that great field of information necessary to intelligent conduct of engineering work and the solution of a great many of our problems, which is not kept secret. For example, in our fatigue phenomena work, which was first financed by the Engineering Foundation with $50,000, the General Electric Co., seeing a great need for investigation in this field, increased the endowment by $30,000 more for a specific work, the results of which, however, were to be freely published.

These then briefly, are my distinctions, and the three groups that I have chosen were chiefly for the purpose of indicating the ways in which this work can best be carried out. For example, in fundamental engineering research the work is not being done to any large extent by individuals or corporations. Some work of that kind, of course, is going on in corporations all the time, but it is not comprehensive, and the comprehensive completion of any one of these big undertakings is so enormous, involves so much expense, that no individual corporation can touch it. I doubt even if the General Electric Co. could attack a problem of that kind, or would care to attack it in the comprehensive fashion that it should be attacked.

I might cite numerous illustrations of that kind, but I think it is safe to say that even at first, during the immediate period following the discovery of this sort, that the public becomes the recipient of the benefits. I know of many cases of that sort where the part of the profit, you might say, appropriated by the corporation is really a much smaller part than that which goes over to the public. An example of this is the very enormous volume of research work conducted by the Western Electric Co. on the telephone instrument that resulted, during a period of rising prices throughout the country, in enabling the telephone companies to continue their rates almost at what they were before.

Doctor Hyde has said in this connection that perhaps we are going too far with research. I think I got his meaning. He didn't mean we were doing too much real research, but that the research idea had spread so far throughout our industries that many men were conducting research and really weren't competent to do so, who really hadn't the scientific foundation, they were floundering around, more or less, and in many cases the results, while apparently some of them were of practical value, went no further, and in many other cases to my personal knowledge were absolutely misleading.

Dr. Hyde's paper will be published in December TRANSACTIONS.

Prof. A. E. White, director Department of Engineering Research, University of Michigan, Ann Arbor, Mich., reads paper "What the University Owes the Industries." This paper appears in full on page 85.

CHAIRMAN HOWE: Dr. G. K. Burgess, chief of division of metal-

lurgy, Bureau of Standards, Washington, is prevented from being with us, but his associate, H. J. French, will present the paper for him.

Mr. French reads Doctor Burgess' paper, "The Role of Government Laboratories in Industrial Research." This paper appears in full on page 91.

CHAIRMAN HOWE: Gentlemen, these various papers are before you for the regular discussion.

MR. LYNCH: I have been much interested in these four papers, and I think, as a rule, they were very clearly put. I think our first paper has outlined the proposition very nicely, with the exception of carrying, instead of a less distance, as our last speaker has suggested, a little further, and making processes to cover those things that have been discovered through research. A great many of our research problems, in my experience, have been such as to be carried to a point by a specialist that, when it becomes necessary to apply it, there is some little thing about it that doesn't work out. In order to make it work out it has been customary to bring in a process and make the specifications. In that way they do get them concrete and down to a clean-cut proposition. By doing that we extend that research in points that may not have been complete. Perhaps they were things that the man who is going to apply it didn't understand, and for that reason didn't make it a success and thereby make a practical application of a scientific research. That point I think perhaps was not covered quite completely enough. It would be my thought that those processes should be, and must be, practical, in order to get them in as research.

PROFESSOR ADAMS: It is wholly a matter of definition. It is just the different picture that one man forms in his mind from another's description. Take the dictionary definition of research and it would certainly cover all that Doctor Hyde covered in his diagram. It is merely a matter of what you agree to call research, but the dictionary certainly covers everything that is there. There is no question about that.

I wonder if you would bear with me for about three minutes while I will say a word about the engineering features of the National Research Council and the engineering societies. We have laid out a plan of organization and are now putting it into effect which ties up those engineering societies at present in a plan for organizing this part of the research that I have called fundamental engineering research, exclusive of those competitive problems which industries naturally prefer to handle themselves. The two illustrations which I gave cover that.

Now the scheme is briefly as follows. In each major field, for instance, in mining and metallurgy, mechanical engineering and electrical engineering, we have a rather large advisory board. That advisory board is usually attached—not always—to the society of major interest in that as its research committee, but at the same time the advisory board, through the Division of Engineering of the National Research Council—and the intention is that the membership of that Board be not confined to the society which we call the sponsor society, but should include representatives from all the other allied societies. That second step hasn't come in as yet, but that is a part of the program, and it is simply a matter of getting the societies to move in a new field.

The membership of these advisory boards is pretty broad and comprehensive, including some of the best experts in the country, including

the representatives of the allied societies. It will include also such representatives from the larger industrial units in that field. The functions of some of these advisory boards are briefly as follows: At first the object is merely to co-ordinate all the work in that field, to get the research talent in that field concentrated on the most important problems under the auspices of the society. The way these boards operated,—and one or two of them are already operating, and very satisfactorily—is this: They get together infrequently, once or twice a year, and comb over the suggestions that have been presented for researches in that field, all, as I say, in this fundamental engineering research. They select a limited number feasible to conduct, or likely to be in hand, and also those most promising, organize subcommittees, one for each of these subjects, with the best group of experts they can pick, plan for meetings and generally act in an advisory capacity to these subcommittees. Now that scheme is working out very well in one or two instances where it is in full operation; in the American Bureau of Welding, under the Welding Society, representing 20 other organizations in that case, and the American Society of Mechanical Engineers, where they had recently a research committee of their own, a central committee, with subcommittees, the whole combination being now attached to the Division of Engineering.

Our purpose is to have the societies themselves take the active part in this work, do all their work in connection with the industry, through to the raising of funds and the conduct of the work. It is impossible with the office staff available in the Division of Engineering to carry out all this work.

One illustration is our highway research program. For reasons of our connections through the Bureau of Public Roads, it was seen advisable to have it sponsored through the individual society, but there are a large number of societies on this advisory board, the Bureau of Public Roads, the Association of State Highway Officials and other interested organizations. That is operating in exactly the same way as the others except that in that case we have enough funds available, already available, to employ a competent high grade engineer for this Advisory Board to devote his whole time to this work, with a staff under him. That Director is Prof. W. K. Hatt, of Purdue University, and that is actually under way.

We have funds available for research all fully in sight now of over half a million dollars a year provided by the Bureau of Public Roads and the State Highway Departments, very largely, and the Department of Agriculture has actually contributed $12,000 a year to the expenses, and several of the states are contributing $1000 or $1500 apiece to that as well, so that the whole thing is run largely by the contributions from the federal government and the states. That is merely an illustration of a little different advisory board. But the whole purpose of the movement is the avoidance of this hit or miss method of conducting research here, there and elsewhere, and the overlapping of effort. What is even quite as important as this is to get our meager—and I speak advisedly—our meager research talent concentrated on the one job, with everybody helping on the job, everybody co-operating.

CHAIRMAN HOWE: I would like to add a word and call your attention to two activities which, on account of my connections, I am particularly interested in. One is called the Alloy Research Associa-

tion, which would have as its official work the gathering of all information that appears throughout the world in all the different languages on the subject of alloys and metals, and publishing that in critical, abstract form and through other committee means of presentation. That is put on by the Division of Engineering and the Division of Research. We have made a beginning in that work and have had to stop until the concerns who must underwrite that sort of thing feel that they can spend the $250 a year for a little trial period to see what can be done in co operation of this sort, co-operatively gathering and disseminating information in as large a field as metals and alloys.

In that connection, we have been told by some that they don't believe the business man wants information, that he gets so engrossed in his pursuit of the dollar that he forgets the point that he must have information to keep himself abreast of the times, and that information is one thing that cannot be obtained co-operatively and used in what may seem private business.

The other thing is something in which Doctor Hyde is particularly connected, being one of the trustees in that enterprise. There, again, the industries must help underwrite that proposition, which we estimate will cost $150,000 to $200,000, and of which a considerable portion is already in hand. But the financial campaign there has had to wait again until the industry feels better about undertaking that sort of work.

MR. MILTON: The president of the American Chemical Society, in an address before the institute in Pittsburgh on chemical research, made the statement that "unless American chemists go back and study the application of chemical research, we will not attain the high standards which we had during the period of the war," and it seems to me that something of this nature is applicable to all research for engineers, to study the methods of the man who has established engineering practices.

MR. STEELE: We have had some difficulties in engineering laboratories in the universities. The engineering research laboratory is interested in a lot of different things, but in every-day work something goes wrong with the bath and it is up to us to get results in a certain time, because everything we use costs money, and we must correct it at once. Now when we have such information in advance we can attack that problem and put our whole force on that problem and correct it. If we must go to two or three universities or other institutions, we don't know whether the man is capable of taking up such trouble or not; we haven't had the contact with him, haven't gotten statistics to know whether he can do it or not. If the trouble is of more of a general nature, one problem of the universities would be to let one man in the university get all the material he wants from the industrial concerns,—the concerns would be very glad to give him quite a bit of material to be of economic assistance, but they don't see the advantage in paying a man at the university to make the test until at least he has shown his worth.

We have in our engineering laboratory rather extensive work done. We could make some tests on fatigue. We have applied it to bearings, and that kind of fatigue tests probably will come out in the work taken up by the fatigue commission. We want to get the results which we can apply. We have a number of problems in connection with this fatigue matter which we would like very much to take up with the gen-

eral university laboratories or whatever it might be, because we cannot afford to hire a man to take up such special problems such as the minute qualities of the steel or various compositions of steel forgings.

LIEUT. COL. WHITE: I might just make this statement with regard to this matter. It has not been the intention in my paper to give a suggestion that by carrying out work at the universities the industrial laboratories or work at different manufacturing plants should be abandoned. I think it is quite generally agreed that the industrial laboratories are exceedingly essential and exceedingly important, and that for carrying on certain features of the plant operation it is exceedingly essential that they operate. I didn't touch on that phase of the subject, assuming possibly that that would be quite generally accepted.

CHAIRMAN HOWE: It seems to me that the problem is very much like the one that exists in medicine, where the physician is eternally busy trying to save the life of his patients. That is a parallel to your factory problem that comes up and must be solved by noon the next day. But there are a number of fundamental problems in medicine upon which someone must be at work, not necessarily with human material, and they will undertake to determine the underlying laws of those problems as a long time research, and therefore we have medical research experts who are working on those problems, and all physicians are making use of those in trying to cure their patients. I think there probably are some fundamentals which should be supported and which must take a long time to solve, while we are trying to solve the immediate problems in the factory. I think the same thing holds true with regard to fatigue research, with magnetic alloys.

OUTLINES AIMS OF S. A. E. RESEARCH DEPARTMENT

(This article is reprinted from a News Bulletin issued by the Society of Automotive Engineers, 29 West Thirty-ninth street, New York. It is of pertinent interest in connection with the Research Session held at the Indianapolis Convention, a report of which appears in this issue of TRANSACTIONS.—Editor.)

PRESIDENT BEECROFT, of the Society of Automotive Engineers, has expressed the view that within less than 10 years the research department which that society has established recently will be of as great magnitude and value to the industry and the country as the society's standards department which is just entering its second decade. Dr. H. C. Dickinson, manager of the S. A. E. research department, in an address before the Detroit section of the society at its opening session of this season, outlined the purposes, aims and possibilities of the department. He said that, in general, the testing of an individual device or any particular material is not included in the definition of research. On the other hand, the study of methods of test as well as the deduction of general information from a systematic series of tests is properly so classed, although to be of value as research the results must be put in such form that they can be of general application.

Development research is recognized as clearly an exclusive function of the individual engineer and the industrial laboratory. By far the largest part of the work of all laboratories connected with the industry is of this nature and as such is recognized by the department as essentially confidential, whereas it is coming to be more and more generally recognized—although we regret, sometimes more as an abstraction than as a course of action—that there is much more to be gained than lost through a free interchange of all research information which is capable of general application. The S. A. E. research department will therefore confine its efforts to explorational and intensive fundamental research. Much work of this nature which is in progress in the industrial laboratories will be of interest to the department and it is hoped that much more such work will be undertaken in the future. But with the major part of the work of these laboratories which is development work, we will not concern ourselves.

An unbelievable amount of time and effort is wasted in the trial of expedients which a more careful application of the fundamental laws of physics and chemistry would have shown at a glance were based on incorrect assumptions. This fact was startingly illustrated during the war when thousands of inventions of every conceivable sort were presented for consideration of the government. It is safe to say that at least 90 per cent of these proposals showed such obvious and fatal errors in fundamental physical and chemical principles that they could be condemned absolutely at a glance. Of course most of them could be condemned equally on practical grounds but one's judgment as to practical possibilities is by no means so safe a guide. Many things which look impractical do actually work but so far as we know nothing works which violates the law of conservation of energy, or the second law of thermodynamics, or Newton's laws of motion, barring Einstein, or any other of a few hundred such principles. Successful engineering research, as well as economical development work, requires men with a peculiar combination of broad fundamental knowledge and sound common sense,

with the enthusiasm of the typical inventor but without his typical shortcomings.

The most common incentive for the organization and continued support of research laboratories or of any systematic research program is necessarily the commercial one. In fact this is almost the only one if we except some of the educational laboratories which have been endowed purely for the sake of the advancement of science. Thus almost every research laboratory and particularly the industrial ones present a constant conflict between these two points of view which are somewhat incompatible. The true research worker is interested in securing facts and will not be satisfied until his results are complete. Moreover, every problem he undertakes presents to him numerous side-lines which are of absorbing interest. If given his own way, unless he is endowed with unusual self-control, he will either carry through his problem to a final conclusion or switch to some side-line of greater interest, according to his temperament. On the other hand, the director of the laboratory or the "man who pays the bills", unless endowed with unusual patience and foresight, will, as soon as some fact of apparent commercial value is developed, recommend dropping the research and developing something useful. A happy compromise between the two points of view is difficult to attain, but a real compromise is necessary since both viewpoints are important and neither side may be neglected.

Up to within the past few years the United States, which has shown by far the greatest industrial development in automotive lines, has contributed comparatively little to the sum of automotive research. The work of British and German experimenters had to serve the needs of our own engineers even though it was entirely inadequate for our needs. In the past few years, however, there has been a general awakening to the need of research among members of the society. We are now awake to the need and once awakened the United States will not lag behind. In fact, perhaps a warning is needed that while the possibilities of research can hardly be overestimated, the realization of these possibilities in terms of industrial results, rests with the engineers in charge of design and development. No matter how many and able the research engineers, nor how important their conclusions, these conclusions will be of value only insofar as they are embodied in successful design.

Aims of the Research Department—In general, the object of the S. A. E. research department is to secure through concerted effort more, and more reliable, fundamental technical information for the use of the members of the society and to make this information more easily available. The distribution of information may be handled in several ways. Fundamental research is in the last analysis almost entirely a question of men rather than of equipment. Many of the most important scientific results have been obtained without laboratory equipment worthy of the name. A study of the research situation in the various laboratories leads to the conclusion that these laboratories are even now sadly undermanned, particularly with men of real ability. To establish a new laboratory could not increase the supply of first-grade research men hence is would have to be manned at the expense of existing institutions. Thus, whatever results the new laboratory might attain would be at the expense of other institutions and the net result probably would not be increased research. It appears therefore that the department can most profitably devote its efforts to assisting existing laboratories.

The three classes of laboratories—educational, industrial, and independent—occupy altogether different positions in regard to research, and any general plan must take account of these differences. It is recognized that the prime object of the industrial laboratories, those directly connected with the various manufacturing companies, must always be development research. But in connection with these we hope there will be accomplished an ever-increasing amount of fundamental research work which can be made of general value,—such work as deals with general principles rather than specific questions of design. It is a common experience to find one laboratory undertaking a research intended to cover some problem which has been carefully covered elsewhere, but no record of which is available. It is one of the aims of the research department to secure, so far as possible, the publication or at least a record of such nonconfidential general results and to act as a clearing house of information on research problems of this character. For the most part, the various laboratories are rather well supplied with problems, but from some institutions where new facilities or new men have become available, there have come requests for suggestions as to problems or general lines of work which might be taken up to advantage. It would seem that here is a splendid opportunity for better use of the educational laboratories by the industry. The custom of farming out individual research problems has been followed to some extent but there is room for much more of it. The S. A. E. research department stands ready to offer any possible assistance in securing more co-operation of this kind.

Duplication of Research—Recently very much caustic criticism has been heard regarding duplication in all sorts of connections, including research. One might make remarks about the duplication in criticism. Research is always a matter of duplication since no physical fact is ever established except through repeated observation. Much apparent duplication is not only desirable but necessary. Nevertheless, this applies to intelligent duplication only. Not much is to be gained by having several different laboratories working on the same problem unless each knows something about what the other is doing. This latter sort of duplication should be avoided particularly among the educational laboratories so far as possible. Since the results of most research are not to be had in print for months or perhaps years after the work is begun, the most pomising means of preventing unnecessary repetition seems to be through some central clearing house for work proposed and in progress. This function the S. A. E. research department will hope to fulfill.

General Research Program—One of the important objects of the S. A. E. research department is to assist toward the development of a more systematic program of research throughout the industry. The formulation of such a program is too much of a problem to be solved for some time to come. It must be built up little by little with the co-operation of the members of the Society of Automotive Engineers.

THE OPTICS OF METALLOGRAPHY

By W. L. Patterson

IN THE best known books on metallography one finds little information concerning the optical instruments used in this study. Some books show illustrations of various types of microscopes, etc., but little is said concerning the manipulation or means of securing the best results with the microscope, the illuminant or the camera. The microscope is an important part of the metallurgical equipment, for by its use we are able to analyze metals according to their structural composition and to make determinations not possible by chemical analysis.

The important parts of the microscope are the optical parts and of these the objectives are probably most important, for it is by the objective that the image is first formed; and the quality and use of the objective determines the final result. The objective is so called because it is nearest to the object. Figs. 1, 2 and 3 show respectively the 16, 4 and 1.9 millimeter objectives of the usual type, but objectives are made in a variety of focal lengths, numerical apertures and styles of mount by various makers. Following are given the usual focal lengths and numerical apertures of achromatic objectives:

Focus Lengths	Numerical Aperture	Type of Lens
Millimeters	0.10	Single achromatic lens
32	0.25	Two achromatic doublets
16	0.50	These three have non-
8	0,85	achromatic front with
4	0.85	two achromatic doublets
3	1.25	6 lenses in all
1.9	1.32	Flourite construction, semi-
1.9		apochromatic

Further reference will be made to the apochromatic objectives later. The focal length of an objective does not indicate its working distance, but means that the combination of lenses composing the objective is equal in focus to a single lens of the stated focus. Thus the working distance for the:

16 millimeter focus	=	7 millimeters
4 "	=	0.30 "
1.9 "	=	0.15 "

An objective may be said to possess seven qualities: Magnifying power; aperture or numerical aperture; resolving power; depth of focus, or penetrating power; illuminating power; flatness of field; and defining power. To fulfill all of these requirements in a satisfactory manner necessitates considerable skill upon the part of the optician. These qualities will be discussed one by one.

Magnifying power usually is stated in the catalogs of various makers in terms of the combination of a certain objective, certain eyepiece and tube length at a predetermined image distance. While tables given in the catalogs are approximately correct, the magnification stated will be obtained only if the conditions given are fulfilled. If the tube length, that is, the distance between objective and eyepiece, is increased or decreased, or an increase or decrease in image distance is taken as in photography, the magnification tables will not prove correct. Tables given in catalogs are often for visual

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A paper presented before the Rochester, Detroit, Pittsburgh, Philadelphia, Cleveland and Indianapolis Chapters. The author, W. L. Patterson, is connected with the Bausch & Lamb Optical Co., Rochester, N. Y.

work and are based on an apparent or virtual image being formed in space at a distance of 250 millimeters from the eye. This apparent size will vary with persons having near or far-sighted eyes, but the normal distance is taken as 250 millimeters and the size of the image is the same if projected on the ground glass of a camera at 250 millimeters.

Makers of objectives also give in their catalogs the initial magnification of their several objectives, that is, the magnification they give at a certain distance unaided by the eyepiece. These tables of initial magnification will be found to vary in different catalogs even though objectives are of the same focal length, this being due to the different systems of calculating magnification. It will be found, however, that for the same focus of objective, the same focus of eyepiece and the same tube length, the figures nearly agree. Some makers use a number system for both eyepieces and objectives, but in making comparisons only focal lengths should be considered.

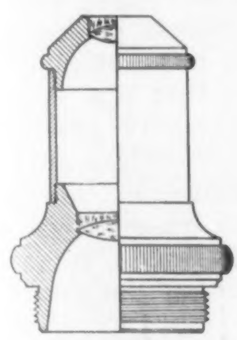


Fig. 1

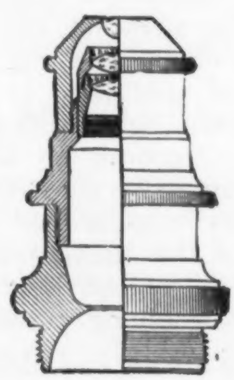


Fig. 2

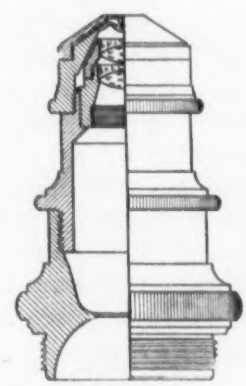
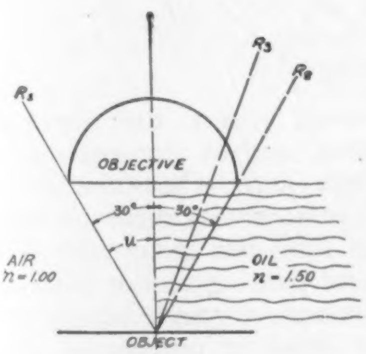
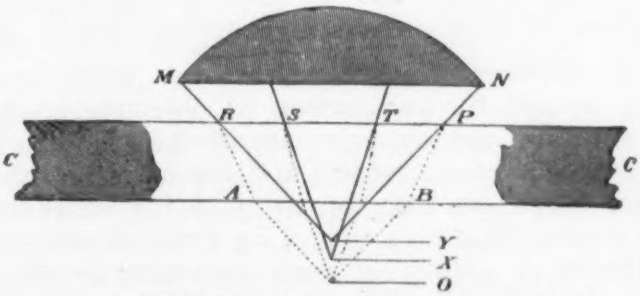


Fig. 3



$N.A. = n \cdot \sin u.$

Fig. 4



The effect produced by a cover-glass on the corrections of an object-glass.

Fig. 5

Aplanatic system. Under-corrected system.

Fig. 6

Fig. 1—16-millimeter objective of usual type. Fig. 2—4-millimeter objective of usual type. Fig. 3—1.9-millimeter objective of usual type. Fig. 4—Diagram showing theory of numerical aperture. Fig. 5—Effect of coverglass upon focus. Fig. 6—Undercorrected system obtained without use of coverglass

In the large inverted forms of metallurgical microscopes the distance between objective and eyepiece is usually about 40 millimeters longer than in the ordinary table microscope and, therefore, the magnification is increased some 25 per cent even with the same focus of objective and eyepiece; hence the difference in magnification tables for this microscope. With the many variable factors in different outfits, it is difficult to make comparisons and it is best to calculate the magnification for the particular outfit being used especially as regards camera magnifications. To obtain the exact magnification at the ground glass of the camera and therefore of the photograph it is best to project a stage micrometer upon the ground glass and measure its magnified image. Micrometers graduated upon metal may be obtained for this purpose. The rulings are in tenths and hundredths of a millimeter. They are placed upon the stage and illuminated the same as a metal specimen. After focusing upon the ground glass the magnification can be measured directly without further calculation.

The aperture or numerical aperture is a property to which many buyers of microscopes probably pay little attention, but it is nevertheless an important quality of an objective. The diagram in Fig. 4 is shown in an attempt to simplify the theory of numerical aperture. If we assume that few if any objects are perfectly smooth, then light is dispersed from every point on the surface of an object in all directions up to 180 degrees. Only an extremely narrow pencil of this can be received by the unaided eye. The apparent problem of practical optics is to be able by means of lenses to gather and bring to a focus as many of the unadmitted rays as possible. In early investigation it was found that the objective which gathered in the greatest angle of rays gave the greatest resolving power.

If only dry objectives were to be considered, we might make a comparison on the basis of angular aperture, that is, the angle of the cone of light which is admitted to the front lens of the objective and reaches the eye. This is important as internal diaphragms reduce apertures, but these apertures may be measured readily by special instruments.

A thorough study by Professor Abbe, however, proved that the only exact method for comparison of objective apertures was by comparison of the sines of the extreme admitted radiant pencils and, when the media differed between the object and the objective, the refractive indices of those media, which are 1.00 for air, 1.33 for water and 1.50 for cedar oil. It is very evident that rays emanating from an object and passing to the objective will travel in a different angle according to the medium through which they pass, owing to the different refractive indices or bending powers of such media.

In Fig. 4 is shown a ray R_1 leaving the object at an angle of 30 degrees, passing through air and just entering the extreme edge of the front lens of the objective. A second ray R_2 leaving the object at the same angle and passing through oil will be bent so as to fall well within the edge of the objective lens, as shown by R_3. It is obvious that a ray leaving the object at a still greater angle than R_2 and passing through oil will be bent so as to pass into the objective. Thus a wider angle of rays is collected in case of the oil immersion objective than in the dry objective.

It will be seen that angular aperture would not be a comparative measure for the two kinds of media. Abbe found that a value could be expressed for the different conditions by taking the sine of one-half of the angle of aperture

and multiplying it by the refractive index of the media between object and objective; hence the formula:

Numerical aperture = n sin u
where n = Refractive index of media air 1.00, water 1.33, oil 1.50
and u = One-half of angular aperture
Thus in the slide the numerical aperture on the air side would be

$$1.00 \times \text{sine } 30^\circ = 1.00 \times .5 = 0.50$$

and on the oil side

$$1.50 \times \text{sine } 30^\circ = 1.50 \times .5 = 0.75$$

This gives a method of comparison between dry and oil immersion objectives. As stated a few minutes ago, numerical aperture plays an important part in the results obtainable with a given objective. The resolving power, which is the property by which an objective shows distinctly separated two small elements in the structure of an object, is directly proportional to the numerical aperture; thus an objective of 0.50 numerical aperture as in the 8 millimeter, has twice the resolving power of the 16 millimeter or 0.25 numerical aperture.

If a very narrow central pencil is used for illumination, the finest detail that can be shown by the microscope, with high enough magnification is equal to $\frac{\text{Lambda}}{\text{numerical aperture}}$ where Lambda is the wave length of the light used for illumination, say one-half micron. The wider the pencil used for illumination, the greater the resolving power until a maximum is reached, when the width of the pencil is sufficient to fill the whole aperture of the objective. In this case the resolving power is twice as great, the finest detail that the objective can show being now equal to $\frac{\text{Lambda}}{2 \text{ x numerical aperture}}$

For an 0 50 objective the first would be one micron with reduced aperture and the second one-half micron with full aperture.

For practical purposes we may take the rule that the numerical aperture multiplied by 100,000 will give the number of lines per inch which can be resolved theoretically by a given objective. Thus, pearlite of say 25,000 laminations per inch should be easily resolved with an 8-millimeter objective of 0.50 numerical aperture and a suitable eyepiece and bellows draw can be used to magnify the image to the size desired, say 400 diameters. On the other hand, an objective of say 0.25 numerical aperture could scarcely be expected to resolve this structure no matter how high we magnify the image by eyepieces or bellows extension. The magnification should never exceed 1000 times the numerical aperture; preferably it should be somewhat less dependent upon the quality of the objective.

Depth of focus (known also as depth of sharpness or penetration) is another important factor which is often not clearly understood. It depends on the numerical aperture and the magnification and is inversely proportional to both. The formula used to express depth of focus is $\frac{1}{\text{numerical aperture}}$; therefore, the higher the numerical aperture and the higher the magnification, the less the depth of focus. It is beyond the power of the optician to change these conditions. Every effort aiming at an increase of the depth of focus, for instance, by inserting diaphragms above the back lens of the objective, must necessarily decrease the effective diameter of the back lens

and thus decrease the numerical aperture, thereby lowering the efficiency of the objective as regards resolving power. It may be advisable at times to introduce such diaphragming for the work to be done, and it will be shown later how such a change can be made by proper use of the illuminating system. However, objectives that show greater depth of focus than others of the same numerical aperture are not well corrected for other qualities.

The illuminating power of an objective is equal to the square of the numerical aperture, and objectives can be so compared; that is, a lens of 0.25 numerical aperture has an illuminating power of 0.062, while one of 0 50 numerical aperture has 0.25 or 4 times as great provided it is used at the same magnification. "Flatness of field as such," said the late Dr. Carpenter, "is an optical impossibility." But by using compensation eyepieces to

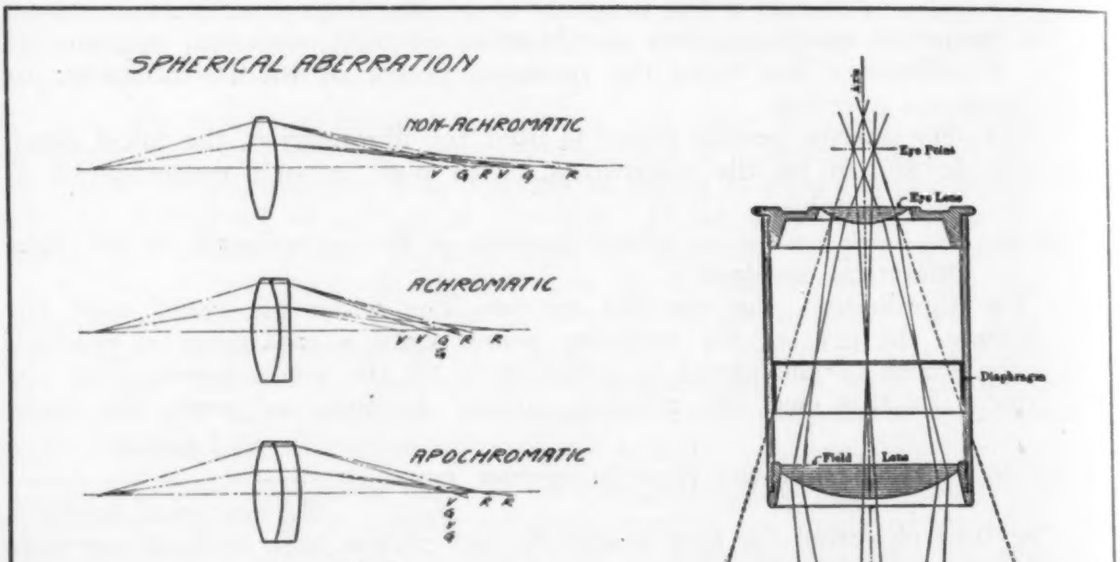


Fig. 7—Illustration of apochromatic lens. Fig. 8—Eyepiece of Huygenian form. Fig. 9—Correction for spherical aberration. Fig. 10—Compensation type eyepiece

Fig. 11

Fig. 12

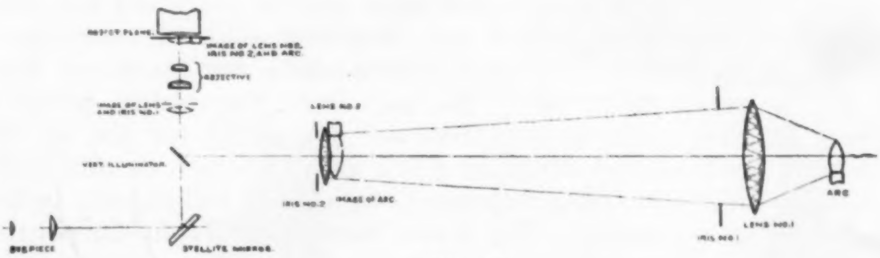


Fig. 13

Fig. 11—Vertical illuminator to which can be fitted mirrors, reflector, plane glass reflector, lenses and diaphragms as desired. Fig. 12—Condenser and iris diaphragm mounted in a separate standard. Fig. 13—Method for obtaining critical illumination

correct the margin of field and by increasing the depth of focus by reducing the aperture, apparent flatness is secured but at the expense of resolving power, as stated before. As an illustration of this we refer again to the statement concerning the depth of focus, which is equal to $\dfrac{1}{\text{numerical aperture}}$; hence, for an objective of 0.50 numerical aperture, the depth would be 2, while for an objective of 0.85 numerical aperture, the depth would be 1.17.

As depth of focus also varies with the magnification, if we use the above lenses at the same magnification we should naturally have greater depth in the objective of 0.50 numerical aperture and if this gives sufficient resolving power for the work in hand it may be used to obtain a flatter field.

Defining power depends upon the finest correction of spherical aberration and chromatic aberration, the perfect centering of the lenses of the objective, and in fact, on the general excellence of the mechanical work involved in the making, and it is here the optician must show his skill. It should be borne in mind that the finer the definition of an objective, the more sensitive it is to incorrect focusing and to slight changes of the adjustment through vibration, etc. In constructing objectives their formulae

should be based upon rigorous computations, all elements of construction such as glass, radii, thickness of lenses separation, etc., being determined in advance wholly without recourse to experiment. This method of construction is the only one insuring uniformity in optical systems of such intricacy as a microscope objective.

It will be well to consider at this time the effect of tube length, that is the distance between objective and the eyepiece with which it is used. Most of the objectives used on biological and smaller metallurgical microscopes are corrected for a mechanical tube length of 160 to 170 millimeters. By mechanical tube length is meant the distance from the shoulder against which the objective screws to the shoulder against which the eyepiece rests. In the case of the larger metallurgical stands of the inverted type this distance is usually longer, owing to reflections necessary to secure an inverted stage and a convenient position for the viewing tube. Therefore, the objectives used on this type of microscope should be corrected for this extra length The use of objectives at incorrect tube length, especially in powers over 100 diameters, will result in inferior definition. This is especially true in metallographic work.

Objectives for metallurgical work must also be corrected for use without coverglass, as specimens of metal are examined without covering.

All objectives used in biological microscopes are corrected for the refraction which takes place when the ray from the object passes through a thin piece of glass. These objectives are not suited for use on uncovered objects and if used in metallurgical work only inferior results will be obtained except with the very lowest powers, such as 16 millimeters or lower. To show the effect of coverglass, Fig. 5 has been taken from Carpenter's book on the microscope. It will be seen that without the coverglass, an ordinary microscope objective would focus at different planes for the central and marginal zones as shown at points *y* and *x* but with the refraction of the coverglass the rays all focus at the point *o*.

Therefore if the ordinary objective is used without coverglass, it will work as an undercorrected system as shown in Fig. 6, whereas when corrected for use without cover the objective should be perfectly aplanatic as shown at the left, all rays focusing at one point. This correction cannot always be accomplished by changing distances between lenses but requires special computation. The oil immersion objective, however, needs no special correction as regards coverglass, because the immersion oil and coverglass are of the same refractive index and if the cover is missing, the additional strata is made up by a thicker layer of oil. The tube length, however, must be correct even in this case.

As to the objective mounts, both long and short mounts are used in metallurgical work. The short mounts should always be used with mirror or prism illuminators so as to bring the illuminator as near to the back focus of the objective as possible. The tendency of late, however, has been to use short mounts for all kinds of illuminators, although Professor Sauveur of Harvard University until recently preferred the long mount with plane glass illuminator. The objectives previously described are of the achromatic type, but the same characteristics are also found in the apochromatic objectives and they are even more sensitive to deviations from the standards for which they are made. The usual focal lengths and numerical apertures are as follows:

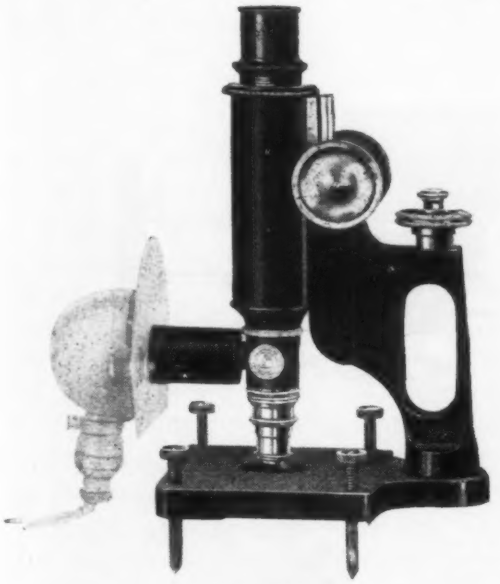


Fig. 14

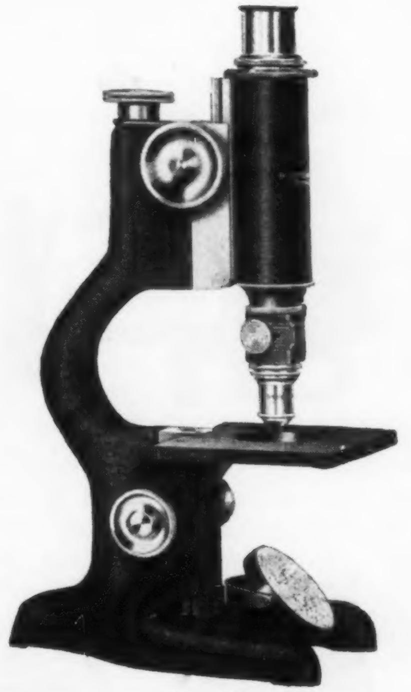


Fig. 15

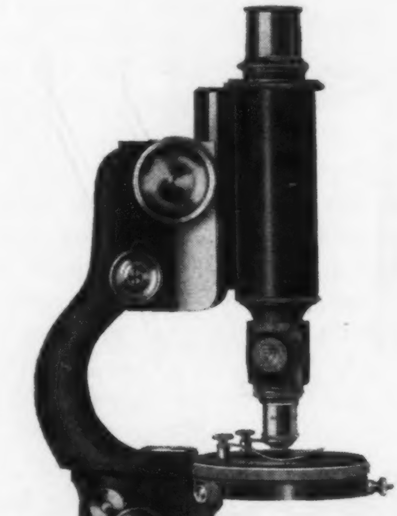


Fig. 16

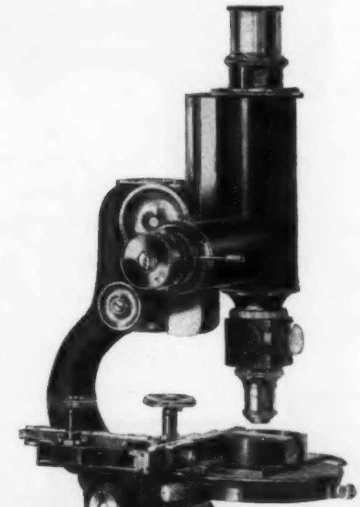


Fig. 17

Fig. 14—Tassin microscope with illuminating device attached to vertical illuminator. Fig. 15—Typical metallurgical microscope for student use. Fig. 16—A stand similar to that in Fig. 15 but having more delicate adjustment and a revolving stage with centering screws. Fig. 17—Fig. 16 with a mechanical stage attached

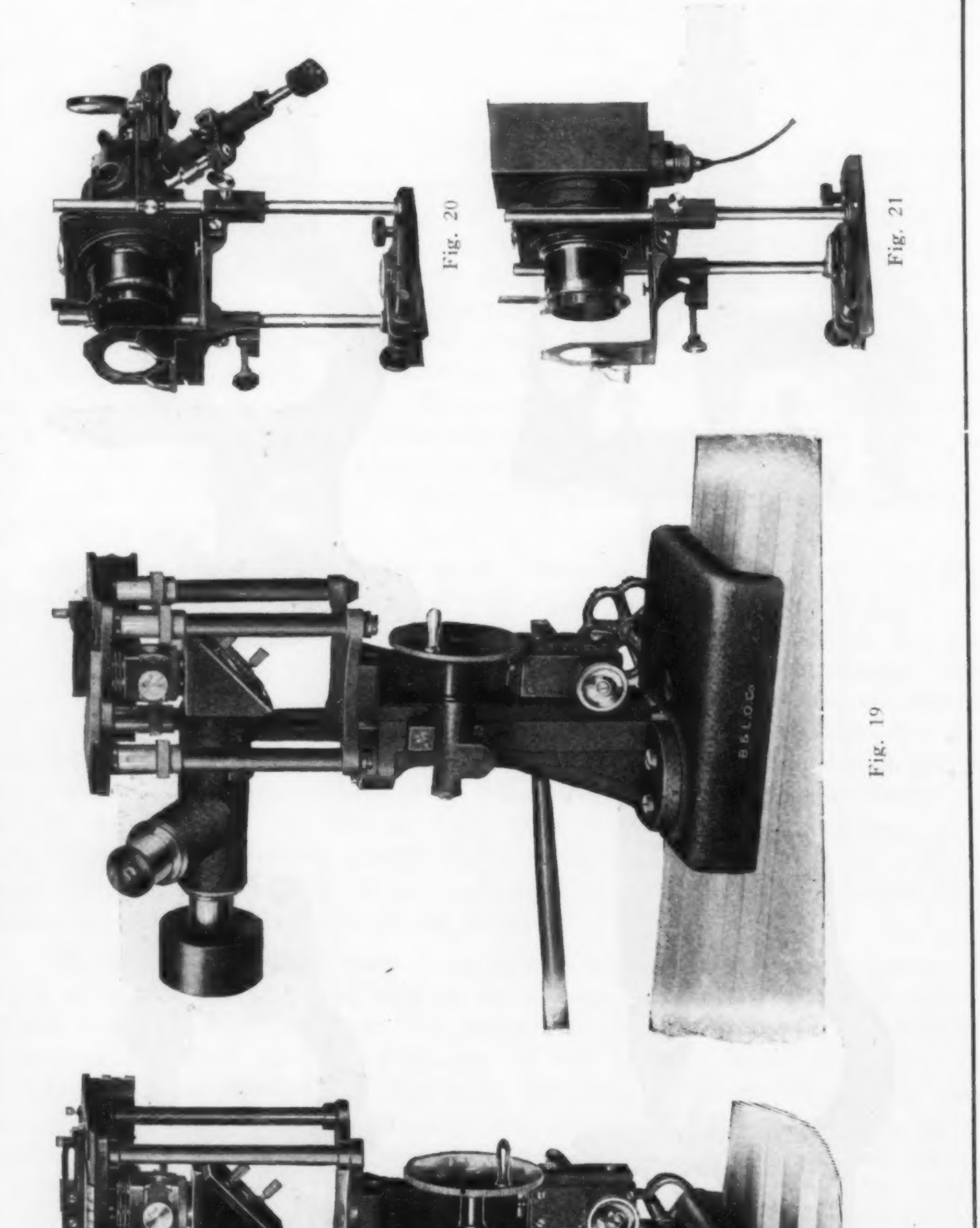


Fig. 18 Fig. 19 Fig. 20 Fig. 21

Fig. 18—Large inverted stand embodying all desirable features of metallurgical microscope. Fig. 19—A modification of the stand shown in Fig. 18.
Fig. 20—An illuminant with arc lamp. Fig. 21—Adaptation of 6-volt lamp to same stand as the arc

Focus Length	Numerical Aperture apochromatic	achromatic
16 millimeters	0.30	0.25
8 "	0.65	0.50
4 "	0.95	0.85
3 "	0.95	0.85
2 "	1.30	1.25

It will be seen that the numerical apertures are somewhat greater in the apochromatic objective. This means increased resolving power and other features attending higher aperture. These lenses have other improvements than increased aperture. The word apochromatic means free of color and is illustrated by Fig. 7. If we were to form an image with an ordinary lens of nonachromatic form, a ray of white light coming from the object would be broken up into the several colors of the spectrum and images would be formed at different distances from the lens corresponding to each color. There would thus be a series of images, one behind the other, ranging from violet to red, the shorter waves being refracted more than the longer ones.

In the standard achromatic objective, two of these colored images would be combined and in apochromatic objectives, three colored images would form in the same plane and as the violet rays are brought to a focus at the same plane as the apple green visual rays, these objectives are excellent for photographic purposes, even when used without filters. As shown by Fig. 9, the correction for spherical aberration is more perfect. Spherical aberration refers to the fact that in an ordinary uncorrected lens the portion of a ray coming through the center and the portion coming through the outer zones are focused at different planes. In the uncorrected lens this applies to all colors; in the achromatic objective the correction is made for one selected color, say green, and in the apochromatic for two colors. Therefore, for the very finest class of investigations the apochromatic objectives are essential owing to their finer color and spherical corrections. These corrections are accomplished by the use of special glasses and a transparent substance known as flourite. Another series of objectives now offered upon the market is the 4-millimeter dry and 1.9-millimeter oil immersions, known as semi-apochromatic objectives. They have one flourite element and are much better than the regular achromatic objectives. They make a good compromise where cost will not permit the purchase of apochromatics.

The second part of the optical equipment to be considered is the eyepiece, so called because it is used near the eye. This may, however, lead to some confusion, as the eyepiece is also necessary when forming the image upon the ground glass of the camera. Some users of this class of apparatus have been found who thought the eyepiece was needed only in visual work. Small photographic lenses are used without eyepieces as later explained. The ordinary eyepiece shown in Fig. 8 is known as the Huygenian form, after its designer. It consists of the two nonachromatic planoconvex lenses with a diaphragm for limiting the field between them. The upper lens is known as the eye lens and the lower as the field lens. Huygenian eyepieces are made in a variety of powers as: 5X, 6.4X, 7.5X, 10X and 12.5X, these designations meaning that they magnify the image formed by the objective by these amounts. Different makers used different designations for their eyepieces and this is liable to cause confusion among different workers if attempt is made at comparison.

In the case of Leitz and Zeiss the eyepieces are numbered from 0 to 5 but the eyepieces of the Bausch & Lomb Optical Co. are marked with their mag-

nifying power as 5X, 10X, etc. Another and better form of eyepiece is known as the compensation eyepiece shown in Fig. 10, so called because it compensates for the variation in size of the blue and red images given by the apochromatic objective. While the apochromatic objective is so constructed as to bring these colors in focus at the same plane as previously stated, the images formed are not of the same size, and this is neutralized by the compensation eyepiece. They should, therefore, always be used when one is using apochromatic objectives and they may be used to good advantage with the high power achromatic objectives. The compensation eyepieces of various makers are not always interchangeable with different apochromatic objectives.

These eyepieces vary in construction and in the number of lenses according to their power. They are made in powers from 5X to 25X, much higher than the Huygenian type, and it is possible to use these high powers with the apochromatic objectives owing to their finer color correction. The slide shows the construction of the higher powers. The compensation eyepiece of Zeiss and Leitz are numbered 2, 4, 6, 8, etc., as in the Huygenian form, but Bausch & Lomb company mark theirs with the magnifying power, as 5X, 10X, etc.

There is another type of eyepiece known as the projection eyepiece, in which the eye lens or lens nearer to the photographic plate is adjustable according to the bellows extension of the camera. With this adjustment one is able to use the objective in the same relative position to the object as it is when used for visual work. Some of these eyepieces have a very small opening in the diaphragm which is liable to indicate that the field is unusually flat.

It is possible to get similar effects as those produced by the projection eyepieces with the ordinary eyepiece, by partially withdrawing them from the eyepiece tube when making photographs. This distance may be found by the formula:

$$\frac{\text{square of eyepiece focus}}{\text{length of camera draw}}$$

Thus for a 5X eyepiece of 50 millimeter focus and a bellows draw of 250 millimeters, the eyepiece would have to be extended 10 millimeters, or it may be determined by experiment. It will be seen that the distance becomes greater with low power eyepieces and short bellows draw. This adjustment keeps the objective in the same relation to the object as when used in visual work, as previously stated, and preserves its best spherical correction tending to flatten the fields. Too much stress cannot be laid upon the necessity of keeping all of the optical parts clean and free from dust, grease or finger marks. Poor results are due to this neglect.

In Carpenter's book on the microscope it is stated that the first vertical illuminator was made and used by Prof. H. L. Smith of Geneva, N. Y. Smith's illuminator consisted of a piece of speculum metal so placed as to reflect light down through one side of the objective, the image returning through the opposite side. The plane glass illuminator is said to have been designed by Beck of England. In this form the light is reflected by the surface of the glass through the objective and the image returns from the specimen through the glass to the eyepiece. Formerly much flare was experienced in using this type of illuminator, but it can be eliminated by proper illuminating appliances and diaphragms. Both forms of illuminator are in use

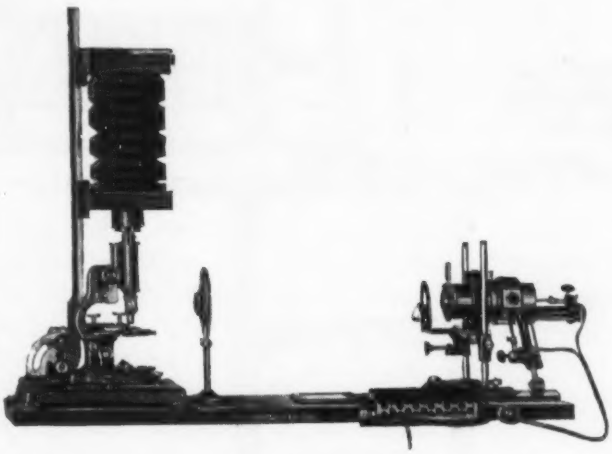


Fig. 22

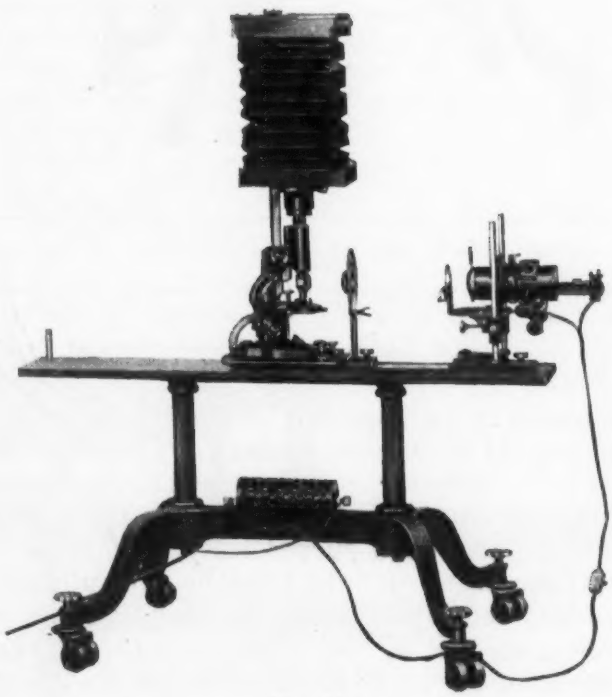


Fig. 23

Fig. 22—Simple type of vertical camera. Fig. 23—A low form of stand with vertical camera

today, the first in the form of mirrors and prisms and the latter much in its original form.

The mirror and prism types are preferred by some workers, and while they are satisfactory for low powers and relief work, they reduce the available aperture of the objective by nearly one-half with consequent reduction in resolving power. They do give increased illumination due to total reflection and may be used for projecting metal specimens with low powers

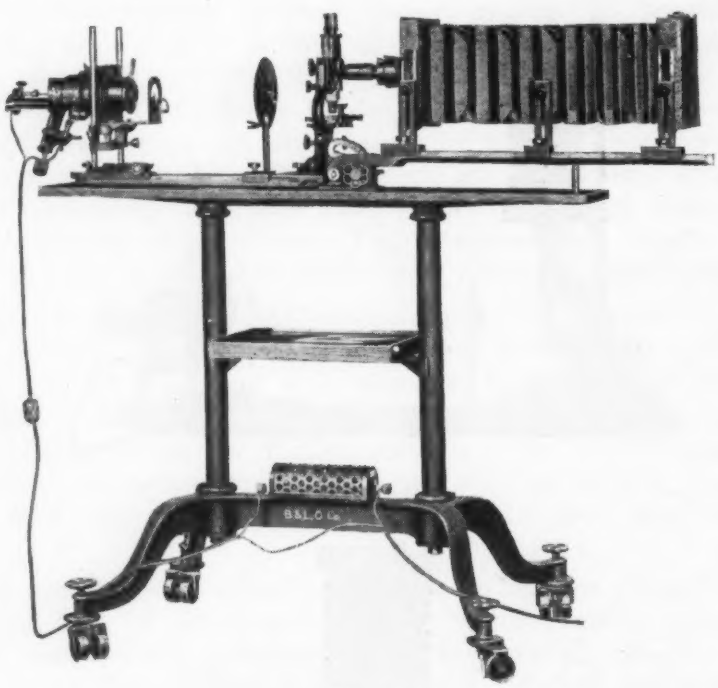


Fig. 24

Fig. 24—A camera specially designed for use with side tube microscope

when several observers wish to study the image, a useful method of demonstrating to executives. For high powers and utmost resolution, the plane glass reflector is best.

Vertical illuminators have appeared from time to time in many forms. The one shown in Fig. 11 is a base model to which can be fitted mirrors, reflector, plane glass reflector, lenses and diaphragms as desired. For visual work and for outfits like the Tassin side tubes with lenses may be attached and used successfully, but when high power illumination is used and the beam of light must be carefully centered to the objective, the best results can be obtained by having condensers on separate standards so that they, as well as the movements of the vertical illuminator, can be adjusted independently. A recent addition to this type of illuminator consists in clamping screws whereby all adjustments can be locked so that once adjusted the illuminator cannot be deranged easily. Care must be exercised to keep the glasses of the illuminator clean and to prevent distortion by bending the mount when cleaning, as it will tend to destroy the definition.

Fig. 12 shows a condenser and iris diaphragm mounted in a separate standard in place of mounting it integral with the vertical illuminator. This is termed by the makers a supplementary condenser, to distinguish it from the condenser at the arc lamp. Its use and adjustment will be explained later.

It is generally agreed by expert microscopists that the best results are obtained when the specimen is examined or photographed with critical illumination. Critical illumination is obtained when the image of the illuminant and specimen are about in one plane, also when removing the eyepiece

and examining the back lens of objective through a pin hole cap, it is possible to entirely fill the lens with light. In Fig. 13 is shown how this kind of illumination may be obtained. The arc or Pointolite illuminant is nearly imaged on the supplementary condenser No. 2 by the aspheric condenser No. 1 with a distance of about 25 to 30 inches between the two lenses. This should give an image of the illuminant of about 25 to 30 millimeters diameter. The image should be slightly ahead of the supplementary lens No. 2 if an arc is used so as to avoid imaging gas bubbles upon the specimen.

An image of the fully and evenly illuminated aspheric lens No. 1 and its iris diaphragm referred later are projected into the back focus of the objective by means of the supplementary condenser No. 2 and the vertical illuminator. The supplementary lens is of such focus and set at such distance from the objective, that is, the same optical distance as the eyepiece diaphragm from objective, that the image of the arc, the evenly illuminated lens No. 2 and its iris, are imaged by the objective upon the specimen when the objective is at proper focus. By closing the iris in front of the aspheric condenser, the aperture of the light cone entering the objective is reduced similarly to that accomplished on some outfits by placing an iris diaphragm on the side of the vertical illuminator but in a better location as it is in the back focus of the objective. This reduction of the light cone below the aperture of the objective gives decreased illumination, and decreases the numerical aperture with attending results, for example, less resolving power, greater depth of focus and greater apparent flatness. Full apertures are obtained with iris opening of 16 millimeters for 4-millimeter objectives and 18 millimeters for 16 and 32-millimeter objectives.

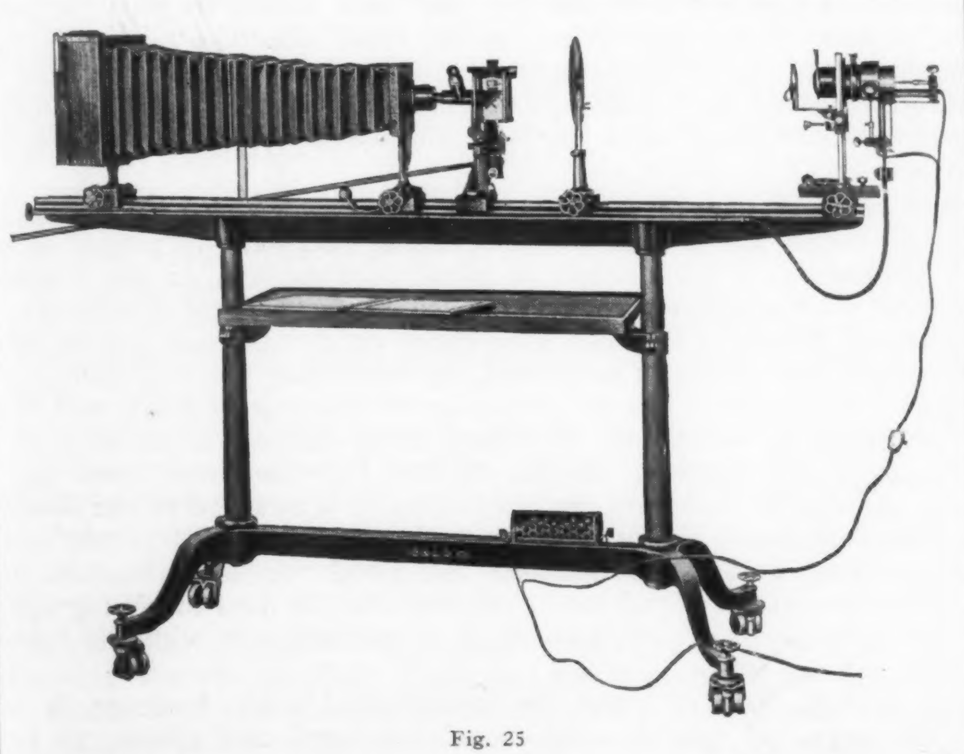


Fig. 25

Fig. 25—GSA type camera used with large inverted microscope IL

The iris of the supplementary lens No. 2 being imaged on the specimen, when closed reduces the size of the illuminated spot upon the specimen, reducing the visible field. By just opening this diaphragm enough to clear the field of view, unnecessary rays are cut off, which rays if they fall on tubes of the objective, illuminator, etc., might cause a flare. The light returning from the specimen after passing through the objective and vertical illuminator, is reflected by a stellite mirror to the eyepiece. The use of a metal mirror reduces all chance of flare which might come from the plane surface of a glass prism.

With the appliances just mentioned, the illumination scheme for metallurgical work as described in the Zeiss circular, Micro No. 89, may be obtained, although the adjustments are somewhat different. It should be noted that in both visual and photographic work decrease in illumination should be accomplished by filters and not by diaphragms which reduce aperture, unless reduction of aperture is desired to secure certain results. Later on will be shown how these optical parts are adjusted to secure the best results as regards centering.

Another method of illumination used on some outfits consists in a supplementary condenser and iris, attached to a side tube, and permanently mounted upon the vertical illuminator. Good work has been done with this form, but this style presupposes that the supplementary lens and iris are correctly centered for each and every objective, which is not always the case. Furthermore, the centering of the illumination is more difficult than is the case where the lens and iris are adjustable. If a ground glass is used in front of the illuminant, the lack of centering is less apparent, but the illumination is greatly reduced and the exposure increased. In experimenting with both methods the adjustable lens and iris has been found to give the best all around results. Some applications of the small side tube on the vertical illuminator reduce the available aperture so that one can best tell how much aperture is used by observing the back lens of objective with a pinhole cap. In some outfits of this kind it has been impossible to obtain fully illuminated objectives.

Any ordinary microscope with proper optics may be used in the examination of metals but it is in this case either necessary to mount each and every specimen at a fixed height to avoid readjustment of the illumination or to have an illuminating device attached to the vertical illuminator, such as the Tassin, shown in Fig. 14. This entire stand was made for the late Dr. Tassin, of the United States navy yard, for examining polished spots on large castings. It is somewhat like the workshop microscopes of Swift and Watson, after the design of Mr. Stead. The illuminating device consists of a 15-Watt incandescent lamp, operating on the regular 110-volt circuit, and two condensers. As can be seen from the illustration, it is attached to the illuminator and moves with it and the optical parts. It may be applied to any ordinary microscope and the results obtained are good for magnifications up to about 200 diameters in visual work. It may also be used in photography for about 100 magnifications, but of course cannot compare with the better instruments and cameras.

The general form of stand for metallurgical work, however, is one in which the stage and specimen are movable by rack and pinion, as by this method varying thicknesses of specimen can be accommodated without deranging the illuminating system. Instruments of this type require the mount-

ing of the specimen in wax or other form of holder. In the case of steel specimens a Sauveur magnetic holder may be used, the specimen being held from the under side by magnetism.

Fig. 15 shows a typical form of metallurgical microscope for student use. This type of microscope was suggested by Professor Sauveur many years ago. Fig. 16 shows a similar stand with more delicate fine adjustment and a revolving stage with centering screws. To this stand may be attached a mechanical stage of the form shown in Fig. 17 This microscope was also designed by Professor Sauveur. It differs from the preceding model in that it has a side tube for connecting to the camera, so that visual observations can be made without disconnecting or moving the camera, the only operation necessary being the withdrawal of the side tube, with its prism, from the optical axis when making visual observation or in adjusting the light and the specimen.

Many workers prefer a stand of the inverted type, that is, one in which the stage is above, instead of below the objective, and in which it is necessary to prepare one surface only, the polished face being placed face down upon the stage over the objective. The inverted form of microscope is credited to Le Chatelier in the year 1897. It has been made in a variety of forms, first by Pellin of Paris, later by Dujardin & Co. of Paris. Other models have been made by Leitz of Germany and Reichert of Austria. A model is said to have been made by Zeiss of Germany, but never appeared on the market.

Fig. 18 shows the large inverted stand of the Bausch & Lomb Optical Co. and embodies all the desirable features of a metallurgical microscope. In this model all parts are of heavy construction and the pieces are limited to the least number to insure rigidity. The rack and pinion are massive and the pinion is operated by a worm which, in addition to giving a smooth slow movement, acts as a locking device and prevents the stage from falling, no matter how large and heavy the specimen may be. The fine adjustment is of the side lever type which automatically compensates for wear. Both adjustments, the rack and pinion and the fine adjustment, move the stage and specimen, the optical parts, including the vertical illuminator, being fixed at all times and when once centered, no change occurs during focusing. The reflector below the vertical illuminator is of stellite, a hard noncorrosive metal. The mechanical stage has all adjustments from below and clamps are provided for holding small specimens and thin sheets of metal under observation.

A modification of this stand is now in use in the laboratories of Dr. Merica of the International Nickel Co. and the American Brass Co. In this modification, shown in Fig. 19, the stage is provided with leveling screws, which makes possible the location of any crystal face perpendicular to the optical axis of the microscope even though this face may not be parallel to the general surface of the specimen.

Other types of metallurgical microscopes which should be mentioned are those of Martens, made by Zeiss, and the Rosenhain microscope, made by Beck. The Marten's stand is of horizontal type, provided with movable stage and is in general form similar to the stands at first described. The specimen must be mounted so as to retain the polished surface in a vertical position. The illuminating apparatus is placed at right angles to the axis of the micro-

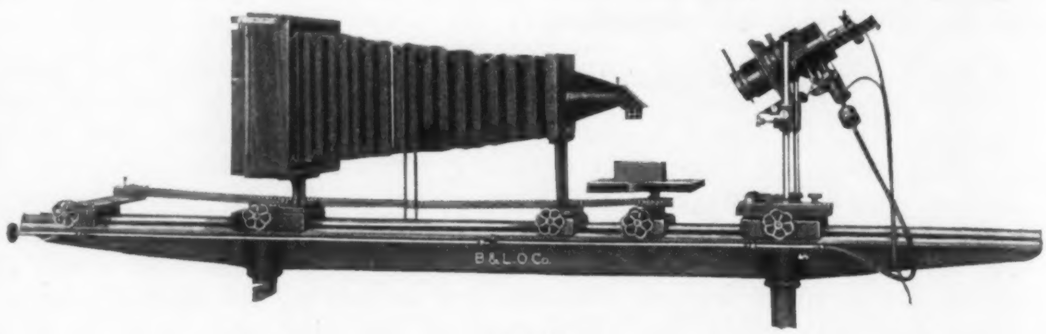


Fig. 26

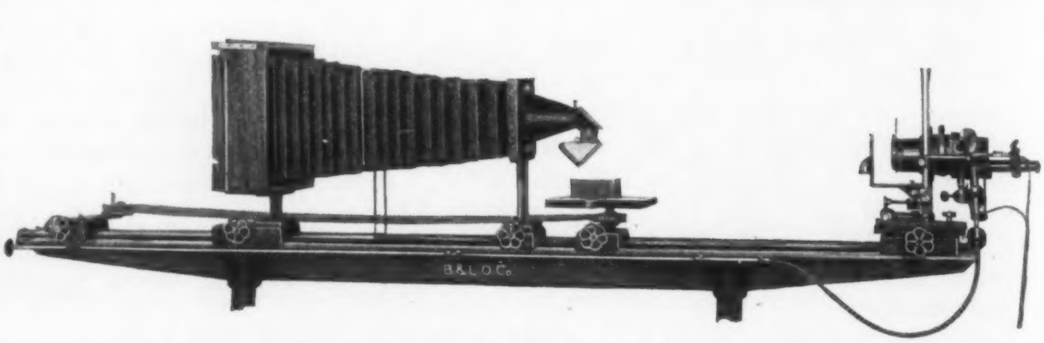


Fig. 27

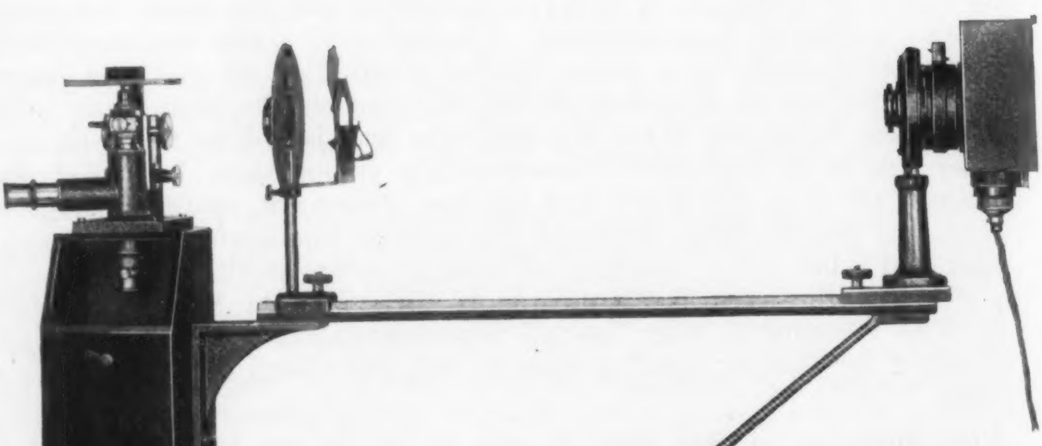


Fig. 28

Fig. 26—Arranged for attaching low-power photographic lenses to camera and device for holding and focusing the specimen. Fig. 27—Plate glass holders supplied for vertical illumination with low-power lenses. Fig. 28—Small metallographic outfit for student use

scope. The Rosenhain is an enlarged and heavy form of usual type and has its vertical illuminator built into the tube.

Suitable illuminant for metallography creates considerable discussion. The direct-current arc with small carbons is no doubt the best illuminant for intensity when used with a good condenser lens. In Fig. 20 is illustrated an illuminant with arc lamp. The condenser in this illuminant is made with special nonspherical curves gathering a cone of about 60 degrees from the arc and forming the rays from all zones into an image in approximately one plane. The ordinary spherical condenser will not do this, as it has what is known as spherical aberration, and the various zones of the lens focus at various planes. The condenser, however, is not chromatically corrected, nor is this necessary in general work. Centering screws are provided to bring the arc in center with the condenser and this is necessary that the condenser may be evenly illuminated, because as shown in a previous illustration, this illuminated lens is projected into the back focus of objective and must illuminate it evenly.

In front of the condenser is an iris diaphragm, which serves to reduce the illumination without reducing the field of view as previously described. A holder is also provided for ray filters and the lamp may be adjusted in both vertical and horizontal directions. It may also be tilted to an angle as much as 45 degrees and used to illuminate large rough specimens or deep etchings in gross photography. A later illustration will show this adjustment. The carbons used in this lamp on direct current are a 5-millimeter horizontal or positive carbon and a 4 millimeter vertical or negative, and it is necessary to see that the positive pole of the current from supply wires is so connected. This may be determined by noting which carbon is brighter. The brighter one should be the horizontal carbon. The positive carbon should heat uniformly over the entire end, and will provided proper voltage is used. It is important that the rheostat, which must be used with the arc be made for the voltage of the supply wire so as to produce 60 volts across the arc. Some users have had trouble in obtaining even illumination because they used a rheostat intended for 110 volts on a current of 100 volts. The lower voltage causes the carbon to heat only on part of the end. When imaged on the supplementary lens only part of the lens is illuminated and, therefore, only part of the specimen is illuminated. While the larger carbons burn longer without adjustment they do not heat evenly, although a 6-millimeter positive and a 5-millimeter negative are fairly good. In an emergency a ground glass may be used to diffuse uneven illumination if it is due to above causes.

Alternating-current arcs are not very satisfactory, as a rule, and yet many are forced to use alternating current. It would be much better to install a rectifier or motor-generator set. If, however, nothing else is available, it may be used with a 5-millimeter horizontal and an 8-millimeter vertical carbon, but the results will not compare with those obtained with direct current. Many users have had success with a 6-volt Mazda lamp of 24 watts capacity on alternating current and one of the metallurgists in the Dow Chemical Co., Midland, Mich., who has made photographs with this lamp at all magnifications, claims results are satisfactory. A better lamp now available for alternating current is the Pointolite to be described later

Fig. 21 shows the adaptation of this 6-volt lamp to the same stand as the arc and one of these lamps should be a part of every outfit for visual work. Critical illumination cannot be obtained, for if the lamp is focused upon the

specimen, the coils will be visible. This can be overcome, however, by so adjusting the aspheric condenser as to diffuse the image of the filament. A higher power incandescent lamp recently has been adapted to this work. It is of 6 volts, 108 watts capacity and gives a brighter and more compact light than the 24-watt. It may be adapted to the same stand.

Another lamp which is now upon the market is known as the Pointolite and probably will solve many of the problems of illumination in photomicrography. The lamp consists of a spherical bulb in which is mounted a very small ball of tungsten. It approaches the ideal point source. By means of a special resistance and ionizing rod, this ball becomes incandescent and gives a fine light. This lamp is now made to interchange with the arc on the standard previously shown, and while not as bright as the arc, it

Fig. 29

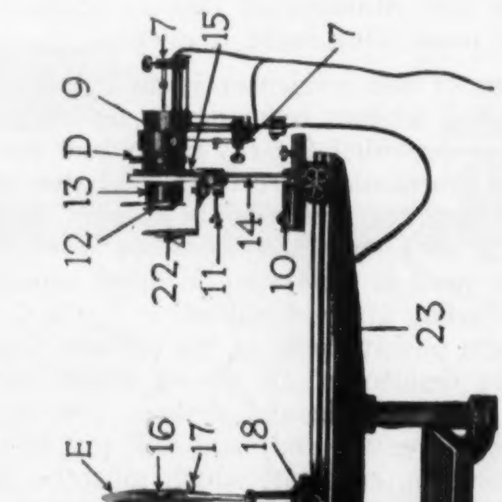


Fig. 30

Fig. 29—Outfit having refinements of large inverted microscope but without appliances carried by larger camera. Fig. 30—Metallographic outfit with parts numbered for reference

gives enough illumination to focus on the ground glass under most conditions and has the advantage of being uniform, steady and automatic. The aspheric condenser magnifies the tungsten ball enough to cover the supplementary lens and, of course, critical illumination can be obtained. While this lamp was originally designed for direct current, a rectifier can now be obtained for use on alternating current. A number of photographs with this light at both high and low magnifications shows it well suited to photomicrography. The spectrum is from 410 to 710. It is hoped that this lamp shortly will be made in this country. The advantage of a stand to which all types of illuminants can be attached is obvious.

The cameras and supports available for this work probably are as great in variety as the microscopes. A few types will be referred to, all of which embody supports to carry an illumination system of the type described. Fig. 22 shows a simple type of vertical camera which has been in use for a number of years. It differs from the ordinary, in that the camera and all accessories are mounted on a single base board to which they can be clamped after adjustment. It is annoying in this work to have a number of loose parts which are readily disturbed. Fig. 23 shows a low form of stand with vertical camera. When resting on the floor the ground glass is at a convenient height for observation. The camera may be swung to one side when making adjustments of the specimen and illumination.

Fig. 24 shows a type especially designed after suggestions of Professor Sauveur for use with the side tube microscope. As stated, when referring to the microscope, the side tube is withdrawn for visual observation and again pushed into the path of light when making photographs. The light-tight connector between camera and microscope is so made that neither camera nor microscope need be moved in making the adjustment from visual to photographic use. All the camera supports described are made with either 4 x 5 or 5 x 7-inch cameras. Fig. 25 shows a camera known as the GSA type and is used with large inverted microscope IL. The camera takes all sizes of plates from 3 x 4 to 8 x 10 inches by means of kits in the plate holders. The larger sizes are useful in gross photography with low magnifications or reductions. Devices for feeding the arc lamp and for adjusting the fine adjustment from a position behind the ground glass are supplied. The arc may also be adjusted while making visual observations, and an adjustable mirror is furnished so that the arc can be observed from all positions. This makes the use of a hand-feed arc convenient. Two focusing screens are supplied, the ground glass for giving a general view of the entire image and a clear glass for fine focusing with focusing glass. These are set at right angles to the axis of the camera and images are formed direct and not by reflection. A plate holder of book form is supplied, and trial exposure may be made by withdrawing dark slide, giving the plate an exposure of 15 seconds; replacing slide 1 inch at a time, giving each succeeding inch 15 seconds, so that the final exposure on a 5-inch plate would be 75 seconds, 60 seconds, 45 seconds, 30 seconds and 15 seconds for the various parts.

After some experience it is easy to judge the correct exposure for a given class of objects. Special appliances are made to meet the requirements of various workers. This camera is also supplied in low form to place on a laboratory bench. In using high powers with all outfits, time must be given for all parts to settle in position, and then make final adjustment of focus. The microscope should be focused, then after a time equal to exposure, the

image should be examined. If still in focus the exposure may be made. If out of focus this operation should be repeated, the exposure postponed until all adjustments have come to rest.

Fig. 26 shows an arrangement for attaching low-power photographic lenses, of the 32, 48 and 72-millimeter foci, to camera, and special device for holding and focusing the specimen. The focusing is done by chain movement from rear of camera while observing the ground glass. It is intended for the photography of fractures etc., and was first made for Dr. Merica of the International Nickel Co. This also shows the illuminant as used for oblique illumination. Plane glass holders were also supplied for vertical illumination with these low power lenses as shown in Fig. 27. A recent paper of the Bureau of Standards shows a number of low power photographs. They were made both with vertical illumination and with incident

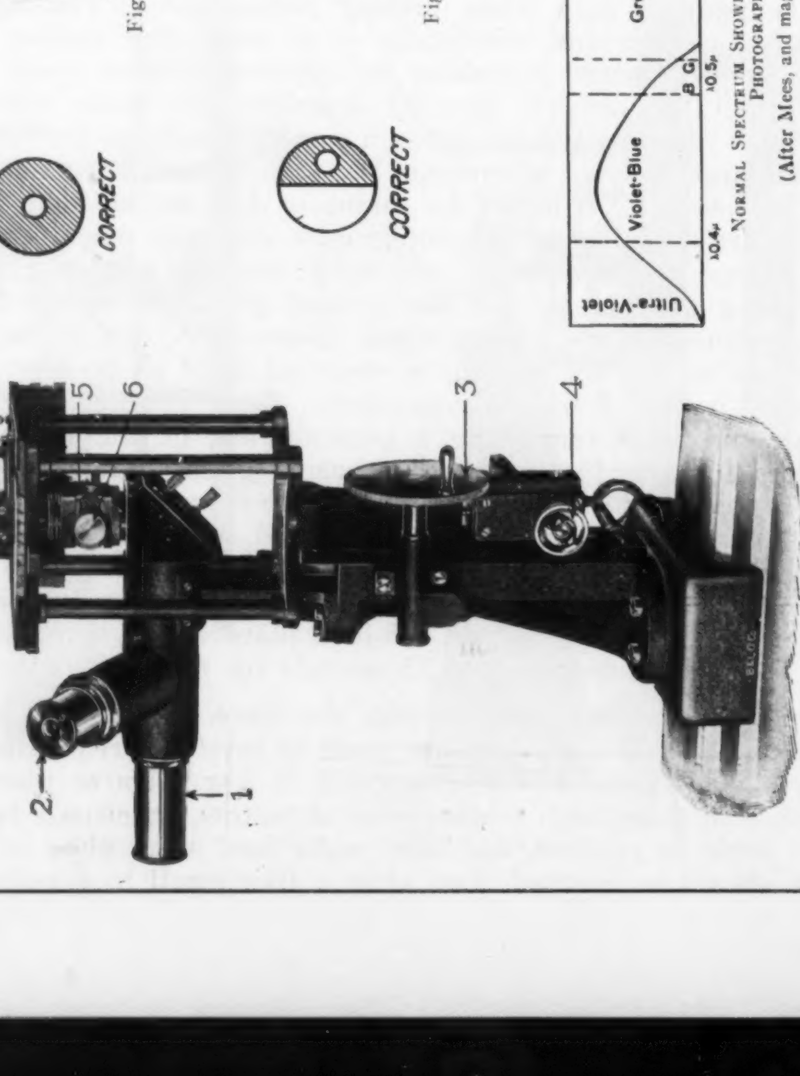


Fig. 31

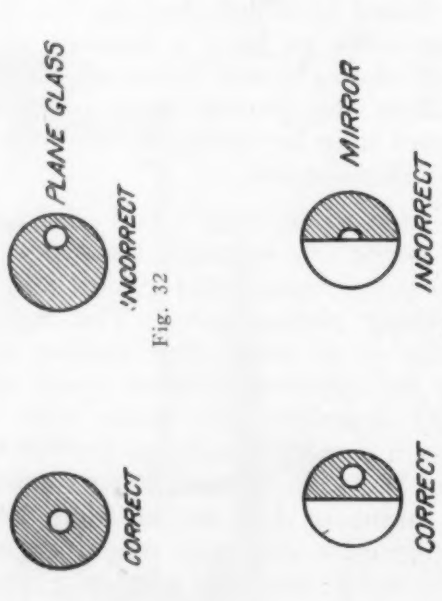
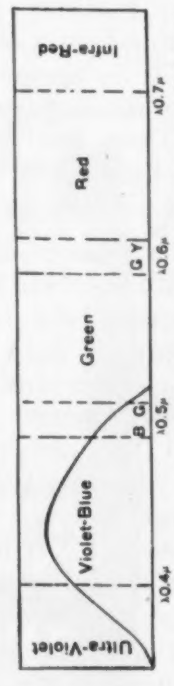


Fig. 32

Fig. 33



Normal Spectrum Showing the Sensitiveness of Ordinary Photographic Plates.

(After Mees, and magnified as in fig. 139).

Fig. 34

Fig. 31—Close view of microscope and plane glass with vertical illuminator set at 45 degrees. Fig. 32—Method of adjusting light spot with plane glass. Fig. 33—Method of adjusting mirror illuminator. Fig. 34—Sensitive region of the ordinary photographic plate

light. Some specimens need to be coated or immersed in alcohol or water to bring out details.

Two new outfits have just appeared upon the market and have not as heretofore been described. The first shown in Fig. 28 is a small outfit for student use and for industrial plants where only a small amount of work at low and medium powers is required. The microscope is of the inverted type and is mounted over the camera. The specimen is examined by means of a side tube which, with its prism may be withdrawn from the optical axis permitting the image to fall upon the plate in the camera. While the image may be focused upon an opaque screen in the camera it is possible to so adjust the camera eyepiece that the image is sharp upon the plate when focused for visual observation. The illuminant may be either the Pointolite or the 6-volt, 108-watt Mazda lamp. The mountings for lamp and the condensers are of much simpler form than in the previous outfits but will give satisfactory results in magnifications from 50 to 400.

The second outfit shown in Fig. 29 has been designed for those who desire the refinements of the large inverted microscope but do not require so large a camera as the 8 x 10-inch or the appliances which this outfit carries. The outfit is solid and gives fine results in photography. The illuminant is of simple form and may be fitted with either the Pointolite or the 6-volt, 108-watt lamp. The condenser is 1½ inches in diameter. The filter holder is mounted upon the supplementary lens stand as is also a simple shutter for making exposures. The microscope is the regular large inverted type and operates in the same manner as previously described. This outfit covers the same range as the usual type of imported apparatus and is lower in price than the large outfit.

Some of the difficulties in the use of metallographic equipment are due to improper adjustment, because it is often found on examining an outfit, that it is not properly centered, or the parts are not in the proper relation to each other. As the large inverted type is now widely used the method of adjustment will be described although these same adjustments apply equally well to smaller outfits fitted with same devices, and instructions may be secured from the makers. One of the main points is the centering and focusing of the illuminating pencil or cone of light. If this is incorrect, good results cannot be obtained. In Fig. 30 the various parts have been numbered for easy reference.

The microscope, *C*, should be 35 inches from the lamp, *D*, so as to obtain an arc image of sufficient size to cover the field, that is, the area of the supplementary lens. If this is not evenly illuminated the field of the objective will not be evenly illuminated. The center of the lamp should be on the same center as the opening of the vertical illuminator, No. 5, and the vertical rods are now graduated to show this position. For preliminary adjustment the supplementary lens should be removed from its standard, and the aspheric lens, No. 13, adjusted so as to give an arc image at a point about 26 inches from the lamp. Then one should close iris, No. 12, in front of arc condenser to a small opening, say ¼ inch. It is assumed that the objective, say 16 millimeters is in position on the vertical illuminator at No. 5.

Fig. 31 shows the microscope closer and the plane glass, No. 6, of the vertical illuminator set at about 45 degrees. Place a highly polished unetched specimen on stage face down, focus objective, and while observing in the eyepiece bring the small spot of light to the center of the field. The

spot should appear as the one in Fig. 32 marked correct. If it is off center, the vertical illuminator should be adjusted either by knob of plane glass, No. 6, or by rotating the illuminator upon the vertical axis until the spot is centrally located.

Going back to Fig. 30 focus the objective roughly and remove eyepiece, No. 2. Place over the eyepiece tube a pin hole diaphragm, for centering the eye with tube. Place supplementary lens, *E,* in position about 6 inches to right of microscope and while observing through pin hole cap, adjust this condenser until the bright spot is in center, as just shown. Then replace eyepiece and close iris, No. 16, of supplementary lens. If the iris is not sharply defined, slide the supplementary lens on its base, No. 18, to or from the microscope until the blades of iris diaphragm can be distinctly seen in the field, when objective is in focus. In making these last observations, the smoked glass cap should be used over the eyepiece. The image of this iris should be concentric with diaphragm of the eyepiece and will be if set-up has been correctly made.

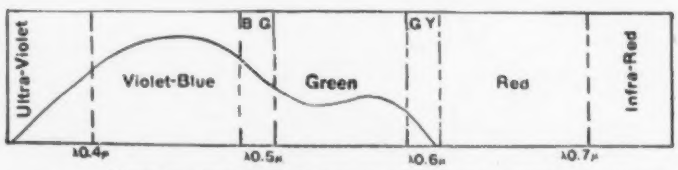
If the arc is now focused on the supplementary lens, the light condition should be as shown as in Fig. 13. Referring to Fig. 31, the arc is nearly focused on supplementary lens, No. 2, by lens, No. 1. Lens and iris, No. 1, are focused at back of objective by lens, No. 2. Arc, lens and iris No. 2, are focused on specimen by the objective. This gives critical illumination. When these results are obtained good images are secured. After a little practice it is not difficult to set up the apparatus in the manner described. Some users introduce a ground glass in front of the arc. This diffuses the light and while giving even illumination, it does not give critical illumination as previously described, but is preferred by some for lower powers and is even recommended by some workers.

In adjusting the mirror illuminator or if a prism illuminator is used the same conditions prevail. The spot of light is to be centered in the field as before and the supplementary lens then placed in position and the location of the light pencil adjusted as shown in Fig. 33. In this case it will be noticed that in the correct position the circle of light is located in the middle of the hemisphere and not centrally with the optical axis. The mirror illuminator is excellent for projecting with low powers. A little practice will enable one quickly to make these adjustments and the results will amply repay for the time spent. The elimination of vibration is one of the difficult problems that most metallurgists have to overcome. No matter how rigid the apparatus, short sharp blows will produce vibrations which make it impossible to make good photomicrographs. There are a number of different devices in use ranging from simple to more elaborate appliances. Each user seems satisfied with his particular device. Probably the simplest and easiest to install consists of two planks, of a size suitable to hold the entire apparatus, and between them two inflated 3½-inch inner tubes or two circles of tennis balls.

Another device much in use consists of a platform suspended from the ceiling, some consisting of simple chains or ropes, others of springs arranged with oil dampers below platform to check the spring movement. Another device designed by Mr. Pafenbach of the Simonds Steel Co., Lockport, N. Y., consists of a submerged platform level with the floor, but suspended upon springs held by angle pieces projecting downward from cross beams, also level with the floor. It seems that each one might best provide such means as are necessary in his particular location, but vibration if it exists,

should be eliminated. Vibration can be detected easily by observing the reflections from a small dish of mercury set upon the apparatus.

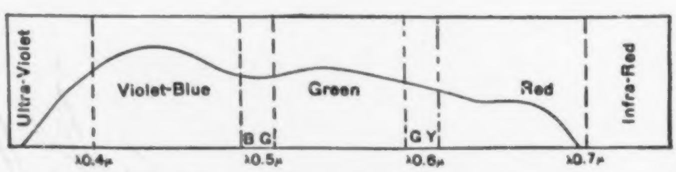
A focusing glass is a desirable addition, and almost necessary if one expects to obtain a sharp image upon the photographic plate, especially in high magnifications. As to the proper color of filter to use in metallography there seems to be some differences of opinion, no doubt due to differences in plates, illuminants, objectives and specimens used by different workers. Different colors have been experimented with and it has been found that on iron and steel specimens a combination of green and yellow dominant wave length of 5500 Augstrom give the best results. Augstrom unit equals one ten millionth of a millimeter. Often the appearance of the image upon



NORMAL SPECTRUM SHOWING THE SENSITIVENESS OF ORTHOCHROMATIC OR ISOCHROMATIC PLATES.

(After Mees; magnification as in fig. 139).

Fig. 35



NORMAL SPECTRUM SHOWING THE SENSITIVENESS OF PANCHROMATIC PLATES.

(After Mees; magnification as in fig. 139).

Fig. 36

Fig. 35—Sensitive region of orthochromatic or isochromatic plates. Fig. 36—Sensitive regions of panchromatic plate for a wide range of the spectrum

the ground glass is made the basis of the proper filter to secure contrast desired but suitable plates must be used to record such an image. Much difficulty is found in obtaining solid glass filters that will give the color desired, so it becomes necessary to use the glass mounted, gelatine stained variety. In the matter of plates one must select a plate suitable to the work and filter used.

Fig. 34 shows the sensitive region of the ordinary plate and if filters are used which transmit only green and yellow with very little blue the exposure will be very long and the results not satisfactory. Fig. 35 shows the sensitive region of the orthochromatic or isochromatic plates and if filters are used such as the B & G Wratten transmitting wave lengths around 5500, this type of plate gives good results. The slower orthochromatic plates have a finer grain and are therefore best for photomicrographic work. Such plates as the Stanley Commercial or the Cramer Slow Iso will give good results. If heat tinted specimens are used and there is much variation in colors all of which one may wish to record, then the panchromatic plate should be

used. Fig. 36 shows that these plates are sensitive to a wide range of the spectrum.

The many factors involved, such as objectives, aperture, magnification, illuminant, filter, etc., make the keeping of records almost imperative. A method of standardizing a photomicrographic outfit has been described by Prof. Alexander Petrunkevitch of Yale University in the Anatomical Record, Vol. 19, No. 5, October, 1920. While his article refers particularly to transparent photography, the same rules can be applied, namely, to determine the best location for each and every part of the apparatus, diaphragm apertures for different objectives, ray filters, plates, etc., and after establishing such record, one may make a picture of a given kind of object in the minimum amount of time and be practically sure of the result without recourse to cut and try methods every time a picture is to be made.

While it is not the purpose of this discussion to talk on the subject of metal, reference should be made to the care necessary in preparing specimens, if good results are to be obtained. The surface of the polished specimen must be flat. Any rocking on the grinding or polishing wheel will produce a cylindrical surface and the field in the microscope will have a band in focus while both sides may be out of focus. We have seen such specimens and had such complaints. Also, the etching must be done properly to produce the contrast necessary to show the structure desired. Light etching has been found to give the best results. It is well again to emphasize the necessity of keeping all parts of the apparatus clean, not only all lenses, but all bearing surfaces. The apparatus should be protected with a rubber cloth covering when not in use, and the metal slide should have a slight coating of vaseline once in a while. The instrument should be placed, if possible, where it is not exposed to the fumes of the chemical laboratory.

EFFECT OF TUNGSTEN CONTENT ON THE SPECIFIC GRAVITY OF HIGH SPEED STEEL

By Arthur S. Townsend

ALTHOUGH it has long been known that high speed steel has a higher specific gravity than carbon steel, a search for authoritative figures on this subject has failed to disclose any complete data. In fact not many figures of any kind could be found. Several of the catalogs of the different tool steel manufacturers mention the fact that high speed steel is heavier than carbon—from 7½ to 15 per cent heavier according to varying estimates. One catalog states that "while the specific gravity of ordinary tool steel is 7.85, that of high speed steel varies from 8.45 to 8.75, depending on the percentage of chromium and tungsten present. Edwards and Kikkawa[1] and Scott[2] give specific gravity determinations on high speed steels, but make no comparisons between steels of different chemical composition.

The reason for the higher specific gravity of these steels is obvious when the specific gravities of the various elements which are used in their manufacture are considered. Tungsten, which is generally present in larger amount than any other element except iron, is one of the heaviest of the chemical elements and the addition of from 10 to 25 per cent of tungsten, therefore, is responsible chiefly for the increase in specific gravity. It is natural to assume that the specific gravity of a steel increases directly as the percentage of metals heavier than iron is increased and conversely that it decreases directly as the percentage of metals lighter than iron is increased. In other words the more there is of an element such as tungsten, the heavier the steel and the more there is of an element like vanadium, the lighter the steel. Table I shows the specific gravities of the various elements used in steel. Additions of carbon, silicon, vanadium, chromium or manganese may be expected to decrease the specific gravity of steel while additions of any of the elements listed after iron should have the opposite effect. Uranium it may be noted is almost as heavy as tungsten, but uranium is only rarely present in steels and then usually only in small amounts.

Observations made in the writer's laboratory from time to time tended to establish the general rule for annealed steels that the higher the tungsten content the higher the specific gravity. A 13 per cent tungsten steel, for example, had a specific gravity of 8.48, while an 18 per cent steel had a specific gravity of 8.70. These experiments together with the theoretical considerations mentioned above suggested that the percentage of tungsten was the principal factor affecting the specific gravity. A systematic investigation was then begun with the object of determining just how close a relation existed between them. The figures which are to follow indicate clearly that the specific gravity of annealed high speed steels increases in direct proportion with the increase in tungsten content, other elements being held constant. The relation between the two is so close and the effect of tungsten content on the specific gravity is so much greater than the effect of any other variable that it has even been found possible to substitute specific gravity

[1] Edwards and Kikkawa. "The Effect of Chromium and Tungsten Upon the Hardening and Tempering of High Speed Tool Steel." Journal of the Iron and Steel Institute, 1915, No. 2, p. 26.
[2] Scott, Howard. "The Relation of the High Temperature Treatment of High Speed Steel to Secondary Hardening and Red Hardness," Scientific Paper of the Bureau of Standards, No. 395, Sept. 16, 1920, p. 528.

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tests for chemical analysis in making tungsten determinations where a high degree of accuracy is not required. A new method for determining tungsten content thus becomes available.

The steels selected for examination were all annealed samples. There were 31 samples of steel in the first collection tested and all of these were carefully analyzed. Three were plain carbon steels, one a carbon steel with 0.46 per cent chromium, one a "tungstenless" high speed steel, two were low tungsten steels and the other 24 were high speed steels with tungsten ranging from 10 to 21 per cent.

Table II gives the percentage of tungsten and the specific gravity found and confirms the general rule given above, although a few slight exceptions may be noted. It also gives the chemical analysis of the samples, the duplicate specific gravity determinations showing how close an agreement was obtained by the method used, and the approximate weights of the samples.

Table I

Specific Gravities of Various Elements Used in Steel*

Element	Specific gravity	Element	Specific gravity
Carbon	1.75-2.10	Cobalt	8.718
Silicon	2.00-2.50	Nickel	8.6 -8.93
Vanadium	6.025	Copper	8.91-8.96
Chromium	6.92	Molybdenum	10.281
Manganese	7.42	Uranium	18.685
Iron	7.85-7.88	Tungsten	18.77

*From Van Nostrand's Chemical Annual.

This preliminary work indicated that the relation between specific gravity and tungsten content was most constant among steels of the same general type. This, of coursse, was to be expected as a number of variables which affect specific gravity are practically eliminated if the steels are all of a common type. It will be noted that 16 of the samples are of the usual type of high speed steel with carbon 0.55-0.81 per cent; chromium 3-4 per cent; vanadium 0.71-1.10 per cent and tungsten 16.5-21 per cent. These sixteen samples and others belonging to the same class were then selected for further study, the idea being that with carbon, chromium and vanadium nearly the same in all the samples, the effect of the tungsten would be ascertained more readily. The results of the subsequent experiments were encouraging and a method was eventually worked out which makes possible the determination of the approximate percentage of tungsten in a sample, the specific gravity alone being known.

A sample weighing about 30 grams is polished roughly to remove scale and "bark" so that a uniform tungsten content is assured. The piece is first weighed in air, then suspended by a fine wire in distilled water and weighed again. It is essential that all bubbles of air be removed from the surface of the piece before taking the weight in water, the easiest way to accomplish this being to dip the piece in alcohol before suspending it in the water. All except a negligible amount of alcohol can be drained off. The weight of the fine wire is deducted and the net weight of the piece in water is subtracted from the weight in air. The specific gravity is then calculated in the usual way. The calculations may be shortened by using a table of logarithms.

An example of an actual determination is given in order to show the simplicity of the calculations.

A—weight of sample in air ....=29.064 grams
B—weight of sample and wire in water ......=25.815 grams
C—weight of wire ....= 0.080 grams

D—weight of sample only in water ....(*B*-*C*)=25.735 grams
Subtracting *D* from *A*:...................*A*=29.064 grams
D=25.735 grams

A-*D*=*E*= 3.329 grams

we get *E*, the loss in weight, representing the weight of the water displaced.

Or using logarithms,

$\log A = 1.46336$
$\log E = 0.52231$

$\text{Log } A - \log E = \log X = \quad 0.94105$

and $X = 8.731$

Referring to Table III we find a specific gravity of 8.73 equivalent to 18.57 per cent tungsten.

A single determination including the calculations can easily be made in 15 minutes, after the specimen has been cut off and polished. The method as adopted was purposely made quite rapid and simple so that it could be used in a practical way for checking tungsten determinations. For this reason, no attention was paid to temperature, atmospheric pressure or similar refinements which would be necessary if the highest accuracy were desired.

Work was done to show that the errors inherent in the determination as performed would not make a difference of more than 0.12 per cent tungsten. If the errors in weighing should total 0.002 grams, assuming that a 30-gram sample is used, the error would amount to only 0.12 per cent tungsten and it is, of course, quite possible to reduce the errors in weighing to less than that.

Much larger errors, however, are introduced due to the segregation or other inequalities in the composition of the samples themselves. Experience with the method seems to indicate that the chief variables which affect the specific gravity beside the tungsten are the percentages of chromium, vanadium, and carbon, the presence of slag or other impurities, presence of microscopic cavities, and density of the steel due to previous rolling or heat treatment. The presence of slag will no doubt cause a marked decrease in specific gravity. The low value obtained for sample No. 9, Table II, may be explained in this way. The presence of slag in this sample is indicated by the high silicon and was confirmed by microscopic examination.

Now if we are able to assume or can show that the carbon, chromium and vanadium are within reasonably well defined limits and that slag or other impurities are present only in extremely small quantities, the variables which cause erratic or unreliable results practically are eliminated. With such samples, it is believed that this method will give results which are accurate to within plus or minus 0.3 per cent. That is, if a sample actually contains 17.50 per cent tungsten, the specific gravity determination should show that it has between 17.20 and 17.80 per cent.

In order to test the method, samples of steel which had never been

Table II

Specific Gravity and Tungsten Content of High Speed Steel

Sample No.	Specific gravity 1	Specific gravity 2	Specific gravity Ave.	Tungsten Per cent	Carbon Per cent	Chromium Per cent	Vanadium Per cent	Manganese Per cent	Silicon Per cent	Phosphorus Per cent	Sulphur Per cent	Cobalt Per cent	Molybdenum Per cent	Uranium Per cent	Weight of sample Grams
1	7.816	7.810	7.813	None	1.32	None	None	0.20	0.59	0.010	0.019	....	....	....	17
2	7.805	7.812	7.809	None	1.15	None	None	0.37	0.59	0.010	0.016	....	....	....	22
3	7.835	7.826	8.831	None	1.36	None	None	0.21	0.20	0.006	0.017	....	....	....	24
4	7.813	7.820	7.817	None	1.17	0.46	None	0.35	0.22	0.022	0.015	....	....	....	14
5	7.877	7.884	7.881	None	0.61	2.28	2.28	0.05	0.14	.....	.....	4.49	5.41	....	38
6	7.877	7.888	7.883	0.85	1.05	0.41	0.25	0.23	0.30	0.023	0.011	....	....	....	27
7	8.011	8.017	8.014	4.34	1.16	0.75	None	0.48	0.41	.....	.....	....	....	....	44
8	8.329	8.309	8.319	10.29	0.37	3.73	0.61	0.28	0.16	.....	.....	None	None	....	33
9	8.210	8.224	8.217	12.24	0.63	4.46	1.70	0.19	2.12	.....	.....	....	....	0.14	30
10	8.516	8.523	8.520	13.53	0.58	2.82	0.30	0.40	0.18	0.031	0.028	....	....	....	27
11	8.468	8.487	8.478	14.30	0.61	3.89	1.37	0.71	0.46	.....	.....	....	....	....	17
12	8.410	8.434	8.422	14.54	0.66	4.65	2.28	0.25	0.47	.....	.....	....	....	....	51
13	8.525	8.537	8.531	15.76	0.72	4.56	1.04	0.12	0.39	.....	.....	....	....	....	31
14	8.625	8.619	8.622	16.47	0.60	3.49	0.89	0.22	0.13	.....	....	....	....	....	23
15	8.626	8.648	8.637	16.82	0.55	3.99	0.86	0.24	0.16	.....	.....	....	....	....	19
16	8.612	8.637	8.625	16.84	0.55	3.42	0.94	0.03	0.33	.....	.....	....	....	....	23
17	8.633	8.636	8.635	17.44	0.62	3.48	0.70	0.30	0.73	.....	.....	....	....	....	26
18	8.684	8.680	8.682	17.47	0.61	3.31	0.89	0.19	0.26	0.024	.....	....	....	....	41
19	8.651	8.628	8.640	17.52	0.66	3.23	0.71	0.36	0.73	.....	.....	....	....	....	24
20	8.691	8.684	8.688	17.64	0.63	3.97	0.84	0.20	0.23	0.040	0.010	....	....	....	46
21	8.656	8.674	8.665	17.68	0.64	3.95	0.93	0.06	0.36	.....	.....	....	....	....	17
22	8.695	8.700	8.698	17.80	0.59	3.04	0.76	0.05	0.51	0.025	.....	....	....	....	42
23	8.686	8.688	8.687	18.21	0.81	3.50	0.90	0.10	0.43	.....	.....	....	....	....	20
24	8.712	8.712	8.712	18.28	0.63	3.86	0.80	0.30	0.23	.....	.....	....	....	....	39
25	8.708	8.700	8.704	18.32	0.68	3.89	1.09	0.17	0.26	.....	.....	....	....	....	28
26	8.728	8.725	8.727	18.42	0.61	3.90	0.74	0.21	0.28	.....	.....	....	....	....	29
27	8.758	8.751	8.755	18.70	0.66	4.87	0.76	0.37	0.35	.....	.....	....	....	....	18
28	8.702	8.711	8.707	18.76	0.67	3.42	0.71	0.26	0.75	.....	.....	....	....	....	23
29	8.776	8.781	8.779	19.17	0.61	4.45	0.82	0.02	0.20	0.017	0.033	2.88	....	....	49
30	8.754	8.760	8.757	19.33	0.64	3.30	0.71	0.17	0.63	.....	.....	....	....	....	27
31	8.810	8.801	8.806	20.90	0.68	3.61	0.74	0.28	0.66	.....	.....	....	....	....	32

analyzed were selected and the tungsten was determined by the specific gravity method. The samples were then analyzed by the usual chemical method and a few of the results obtained are recorded here in order to show the degree of accuracy that may be expected.

Specific gravity method tungsten, per cent	Chemical analysis method tungsten, per cent
18.16	18.01
18.37	17.94
18.37	18.68
19.39	19.57
18.57	18.32
17.14	17.16
16.73	16.88
19.18	19.21

Table III gives the percentage of tungsten corresponding to any given specific gravity for annealed chrome-tungsten-vanadium steel of the general type mentioned above. The values in this table were obtained as follows: The figure 7.82 was adopted as a base, this being the average specific gravity obtained for the carbon steels. The difference between the specific gravity of the high speed sample and 7.82 then represents the increase due to the tungsten in the steel. If this increase be divided by the percentage of tungsten present as shown by chemical analysis, a quotient is obtained which may be called the factor for that particular sample. For instance, given a specific gravity of 8.70 and a tungsten content of 18.21 per cent, the increase is 8.70—7.82 or 0.88. Thus 0.88 divided by 18.21 gives a factor of 0.0483. After a sufficiently large number of determinations had been made these factors were calculated and averaged and the average factor being very close to 0.0490, this was adopted as the factor for all steels of this type. With 7.82 as the base and 0.0490 as the factor, the figures given in Table III are then easily arrived at. For example, 8.68—7.82=0.86 and 0.86 divided by 0.0490=17.55 per cent tungsten.

It should be understood that this table gives approximate or average values, not exact determinations which hold true in every case. Not every

Table III

Specific Gravity Corresponding to Tungsten Content

Specific gravity	Equivalent tungsten per cent	Variation per cent ±	Specific gravity	Equivalent tungsten per cent	Variation per cent ±
8.60	15.92	.30	8.70	17.96	.30
8.61	16.12	.30	8.71	18.16	.30
8.62	16.33	.30	8.72	18.37	.30
8.63	16.53	.30	8.73	18.57	.30
8.64	16.73	.30	8.74	18.78	.30
8.65	16.94	.30	8.75	18.98	.30
8.66	17.14	.30	8.76	19.18	.30
8.67	17.35	.30	8.77	19.39	.30
8.68	17.55	.30	8.78	19.59	.30
8.69	17.76	.30	8.79	19.80	.30
			8.80	20.00	.30

steel with a specific gravity of 8.66, for example, will have exactly 17.14 per cent tungsten, nor will every steel with 17.14 per cent tungsten have a specific gravity of 8.66, but the table is written in this form for the sake of simplicity and convenience and it gives values which are probably very close for steels of this type.

The usefulness of such a table to the analytical chemist in the steel laboratory is obvious. By means of specific gravity determinations, the results of chemical analysis for tungsten may be quickly checked and any large errors are easily detected. This practice leads to greater accuracy in the chemical analysis.

In case the chemical and physical determinations do not agree and both have been carefully checked, the chemist or metallurgist may then feel assured that the bar of steel in question is out of line in some other respect. Possibly the vanadium content is high or low, or the steel contains an unusually large amount of impurities. It may or may not be defective, but at any rate it is different from the regular steel. In this way, specific gravity determinations aid the metallurgist who is desirous of securing and maintaining a supply of uniform material.

Such determinations also give additional information to the research worker who is studying the properties of high speed steel. In connection with other tests such as miscroscopic examination, fractures, hardness tests and chemical analysis, the specific gravity test gives one more item of information and it is the combination of all these tests which gives the complete record of the quality of a steel.

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DISCUSSION OF THE HARDENING OF STEEL AND OTHER ALLOYS

By Oscar E. Harder

TO DISCUSS the phenomena of hardening of steel and other alloys, with particular emphasis on the important part played by solution and precipitation is the purpose of this paper. It is hoped that it may serve to put into simple language certain explanations which are in keeping with the well understood reactions in related subjects.

Considerable information regarding the mechanism of solution and precipitation can be drawn from the field of chemistry. This information includes the thermal changes accompanying solution and precipitation, the formation and growth of crystals, the supercooling of solutions, the effect of crystal nuclei on the beginning of crystallization, the effect of foreign matter which may accelerate or retard crystallization, the changes in volume due to solution and precipitation, the growth of large crystals at the expense of the small ones, the effect of the ratio of solvent to solute, the increase in the surface tension due to irregular surface, the effect of surface films on the shape of a plastic body, etc.

Probably the most satisfactory method of attacking this problem is to state first of all, in so far as possible, just what takes place in the heating and cooling of steel. Adhering to the observed phenomena and established facts, let us consider an annealed piece of steel containing less than the eutectoid, for example 0.7 per cent of carbon. We may regard this as an alloy of iron and carbon, or, what seems more satisfactory, a binary system—iron-iron carbide. In this annealed product we have two phases present, the pure iron and the carbide of iron.[1] The shape and size of phases observed in this annealed steel will depend upon the exact heat treatment to which it has been subjected. If the annealing has been complete and the rate of cooling very slow we may have all, or nearly all, of the cementite or carbide of iron in the granular form, as shown by Fig. 1. If the rate of cooling is more rapid, then the particles of carbide will be of more irregular shape, have greater surfaces and be of that lamellar form known as pearlite as shown by Fig. 2, or even of that form known as sorbite as shown by Fig 3. While the microconstituents shown in these photomicrographs have been obtained by treatments different from those mentioned above, their appearance is essentially the same.

For this discussion it is desirable to assume a complete decomposition into pure iron and carbide. A calculation of the phases present at ordinary temperatures by means of the inverse lever arm relations about the point 0.7 per cent carbon with the arm extending to the composition of the phases present shows that there would be 10.5 per cent of cementite and 89.5 per cent of ferrite.

$$\text{Ferrite} = (6.68-0.7)100/6.68$$
$$\text{Cementite} = 0.7 \times 100/6.68$$

1. By phase is meant a mass of material which is chemically and physically homogeneous, but physically distinct and mechanically separable. It should be understood that these terms are relative and that when we say that a phase is physically homogeneous we mean that our present methods of examination do not disclose heterogeneity. Likewise, what we term a phase may in reality be an aggregate, but our present means of examination does not disclose that fact.

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Let us assume that this annealed alloy is heated. As heating progresses a temperature is reached at which a solution of the iron and iron carbide begins. Because of the custom of designating as solvent that phase which is present in larger amount, we may assume that the pure iron is the solvent and the carbide the solute. However, it is probably a case of mutual solubility. The result of this reaction is that these two phases combine to form one phase which is known as a solid solution and which is considered to be essentially similar to ordinary solutions. Therefore, we are not surprised to observe an endothermic reaction due to the heat of solution. This is the well known decalescence point which is observed in heating steel, especially those steels containing a considerable percentage of carbon, and is usually dsignated by the Ac_1 line. It is also generally true that the volume of a solution is less than the sum of the volumes of the solvent and the solute. Therefore, it seems reasonable to expect a decrease in the volume of the steel after this reaction. [2] As this reaction progresses all of the carbide as such disappears. A calculation just above the temperature at which this reaction is completed will show the amounts of the two phases to be about 77.8 per cent of the solid solution and 22.2 per cent of excess pure iron. This calculation assumes a carbon content of 0.9 per cent in eutectoid steel. Here the phase in larger amount is the solid solution and it is considered the solvent and the pure iron will go into solution and as it does so the heat of solution will be taken up. Likewise there should be a decrease in volume as explained above. Having obtained a homogeneous solution we may expect the volume and the heat absorption to vary with the temperature of the mass.

Solutions of this type are referred to as solid solutions because of their lack of fluidity. However, there seems to be no reason for treating them or their properties differently from ordinary solutions. In this particular case it may be assumed that the individual particle to be considered is either the atom or the molecule. Recent work in the field of X-ray analysis favors the atom as the individual particle in metals and alloys. The phenomena of association and dissociation cannot be studied with the same ease that they can in aqueous solutions, but they seem of minor importance in the present discussion. We are primarily interested in the solution of intermetallic compounds and the results obtained by retarding the precipitation of these compounds so that they do not separate, or the separation is delayed to abnormally low temperatures.

By cooling the solid solution discussed above, a temperature will be reached at which it will become supersaturated with reference to one or more of its constituents and there will develop a tendency for it to precipitate. Some of the factors which influence this process are: The tendency to form crystal nuclei; the growth of the crystal nuclei; the effect of foreign substances; the rate of cooling; the shape of the container; the amount of agitation, etc.

As precipitation continues the solution contains less and less of the pure iron and more and more of the carbide.[3] Finally a concentration is reached at which it is supersaturated with respect to both the iron and the carbide and the two precipitate simultaneously. The mechanism of precipitation may be accounted for conveniently by the formation of crystal nuclei which form when a certain minimum number of the particles in solution collect

2. Sauveur, The Metallography and Heat Treatment of Iron and Steel, p. 199.

3. Investigators are not entirely agreed as to whether the carbon in the solid solution is free or combined with iron. However, the precipitate is the carbide.

and arrange themselves according to a space lattice characteristic of that substance. What this minimum number is has not been determined and the size of the crystal which could first be detected would depend upon our means of observation. Thus in ordinary solutions we have the molecules or ions; then that size of particle known as the colloid, which according to Ostwald[4] has a size of between 0.01 *u* and 1 *uu* (1 x 50^{-5} and 1 x 10^{-7} centimeters) or a specific surface between 6.10^5 and 6.10^7; true or coarse dispersions; and, finally, the size which may be seen with moderate or no magnification. However, in the case of the steel under discussion the size of the particles after slow cooling is such that they can be seen under magnifications of X1000 or even less.

When crystals separate from a solution there is heat evolved, which amount should correspond exactly to the heat absorbed in solution. So as the precipitation of pure iron begins there should be an evolution of heat and this causes the arrest on the cooling of steel. The magnitude of this arrest depends upon the relative amount of material precipitated. A calculation will show that theoretically 22.2 per cent of the steel by weight will precipitate as pure iron through a temperature range of about 20 degrees Cent. Since this heat effect is rather small, and is distributed over a considerable temperature interval, the arrest is not pronounced nor should that change in volume be great. However, when the solid solution becomes supersaturated with respect to both the iron and the carbide and simultaneous precipitation takes place, the remaining 77.8 per cent of the steel precipitates at a constant temperature. This large evolution of heat produces the well-known recalescence point in high carbon steels, usually indicated as the Ar_1 line. This reaction should also be accompanied by a large change in volume because a solution changes to a solvent and a solute by precipitation.

As is well known the hardening of steel is accomplished by rapid cooling. Let us take a case in which cooling has been so rapid that no precipitation has taken place. Practically this is not possible with plain carbon steels except with very high carbon content. We have retained at ordinary temperatures the solid solution which is now in a metastable[5] condition. There is a certain minimum temperature to which this solution can be cooled before it passes into the instable[6] region, and precipitation may result. The rate of precipitation depends upon a number of factors. Other conditions being fixed, the higher the temperature the more rapidly will precipitation take place. Presumably the size of the particle in solution in the metastable solution is the same as that of the solid solution at the higher temperatures, and the size of the individual particles will be 1 *uu* or less. Now as precipitation takes place there will be an accumulation of these small particles, atoms or molecules, into larger masses which finally grow to such size that they can be seen at moderate magnifications of say X1000. It is obvious, therefore that these particles must pass through all the intermediate sizes from that of the submicroscopic, atom or molecule, to that of the microscopic. This range includes that size of particle generally referred to as the colloid. Referring again to the hardened steel in which there was no precipitation and in which a solid solution was obtained in a metastable condition, the metastable condition may be changed to the instable condition by different methods: 1. Cooling to lower temperatures[7]; 2. heating to higher temperatures[8]; 3. me-

4. Ostwald, Fischer, "Handbook of Colloid Chemistry," p. 33.
5. Findlay, The Phase Rule, pp. 30 and 77.
6. Findlay, loc cit.
7. Hoyt, Metallography, Part II, p. 164.
8. Monypenny, J. Iron & Steel Inst. 101, No. 1, p. 493. Also Andrews, et al, Ibid. p. 601.

chanical treatment[9]. If the instable condition is reached by cooling to a lower temperature then the precipitation would be very slow and presumably after a considerable time the precipitation might still be incomplete. Such solutions should show a decreasing tendency to form crystal nuclei and a decreasing growth of crystals as the concentration decreases. On the other hand, if instability is brought about by heating to higher temperatures the

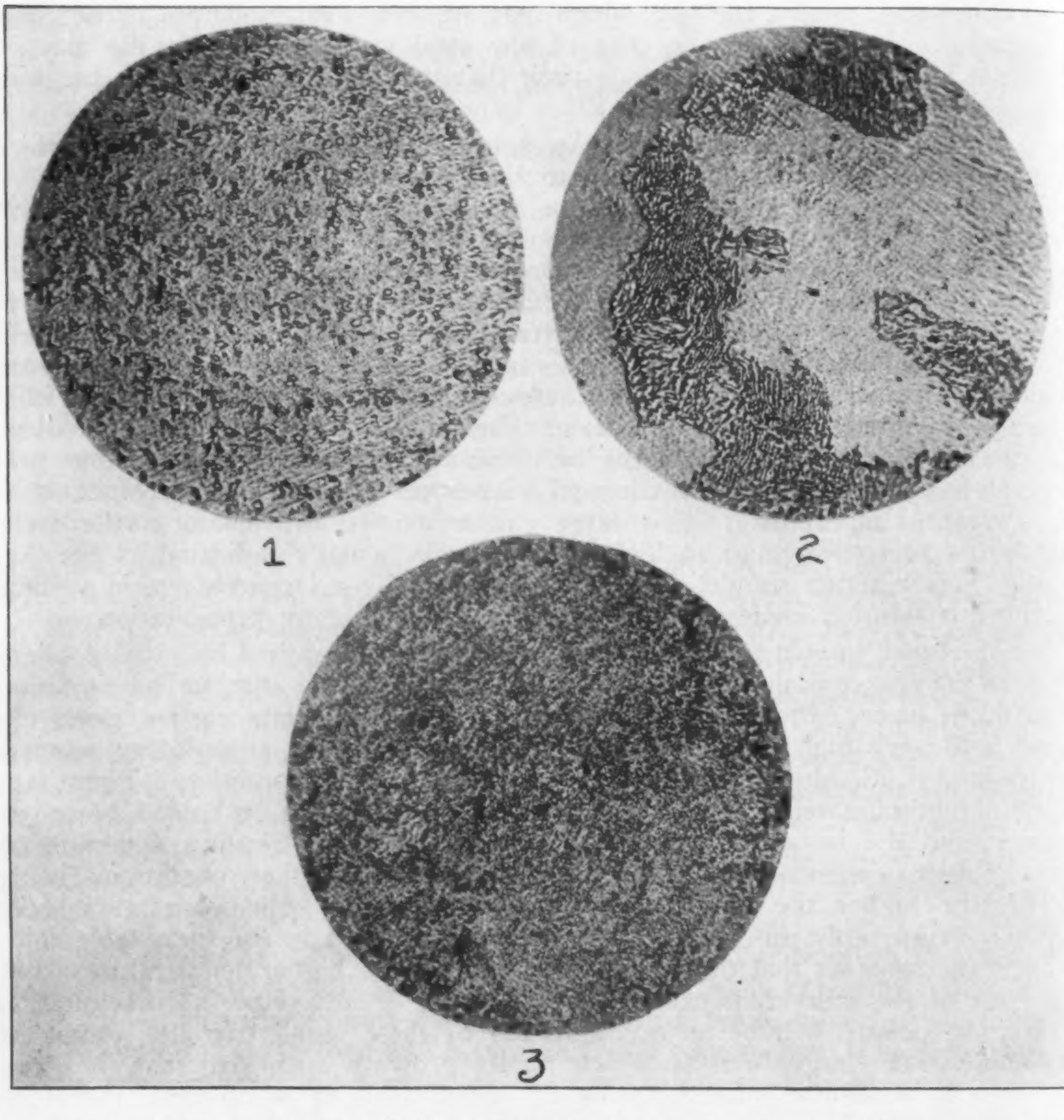

Fig. 1—Cementite. 0.40 per cent carbon steel quenched from 900 degrees Cent. in water; reheated to 690 degrees Cent. for 21 hours and air cooled. Fig. 2—Pearlitic cast steel of 0.40 per cent carbon. Fig. 3—Sorbitic 0.35 per cent steel, quenched in water from 850 degrees Cent.; reheated to 600 degrees Cent. and air cooled. All specimens etched with picric acid in alcohol and X 1000.

precipitation when once started would be more rapid and therefore go to completion in a shorter time or more nearly reach completion in a given time. The change from the metastable to the instable condition probably accounts for all that really happens in the so-called crystallization of metals under fatigue or vibration. Likewise, it probably accounts for the observed

9. Howe, Proc. A. S. T. M. 17, II, 5-8 (1917). Monypenny, loc cit.

hardening of high manganese steels in such service as crushers and ball mills[10].

Such quenched steels which have been retained in the form of solid solutions at ordinary temperatures are known as austenitic steels and that micro-constituent as austenite[11]. It is known that these steels do not show the ordinary arrests when cooled sufficiently rapidly to retain them in the austenitic condition. However, when they are cooled to lower temperatures so that the transformation takes place there is a heat evolution. Also when the transformation is brought about by heating there is observed a heat evolution[12]. Austenitic steel does not show, under our present microscopes, any particles of the iron carbide. While it shows crystals and individual grains on deep etching, it shows neither pure iron nor pure carbide.

If the transformation takes place upon lowering the temperature, or upon heating, there is observed a heat evolution such as might be expected had the transformation taken place upon slow cooling, and the other phenomena which would accompany precipitation are observed. However, if this steel is examined under the miscroscope only a single phase will be observed. At a magnification of one thousand or somewhat more, we are not able to observe any particles of cementite. It seems reasonable, therefore, to assume that precipitation and crystallization have taken place, as indicated by the heat evolution, and that we have, instead of a solid solution, a precipitate of iron carbide in a very finely divided condition, probably the magnitude of the particles being near that which is usually designated as the colloidal particle, and either the pure iron from which the carbide has been precipitated, or possibly a certain amount of the original solid solution from which the precipitation of the carbide is not yet complete. This precipitation results in two phases, or the solvent and solute, which we may expect to occupy a greater volume than the original solution and, therefore, produce the increase in volume frequently observed in hardened steel, and as a consequence, the enormous stresses which in some cases are sufficient to break large cylinders of hardened steel. If the carbide were precipitated in this finely divided condition, it would have a larger surface and a larger volume than it could have with any increase in size of particles.

The conditions mentioned above would seem to account for the properties of martensitic steel, which may be obtained by cooling austenitic steel to very low temperatures, by heating it for a period of time at a low drawing temperature, by stressing austenitic steel, or by cooling it at a less rapid rate than indicated above so that precipitation is retarded but takes place somewhat before it reaches ordinary temperature.

If steel of the type referred to as martensitic steel, is heated to increasingly higher temperatures, it is well known that it becomes softer, stresses are removed, and soon particles of carbide appear which can be distinguished under the microscope. This would seem to be a process of collection of the small particles, probably colloidal, in martensitic steel into larger and larger particles. The mechanism of this growth of particles might be through a dilute solution of the carbide similar to the growth of certain crystals in aqueous solutions where the large crystals increase in size, the small crystals decrease in size and finally disappear, or possibly this growth might take place through the amorphous material surrounding the grain boundaries. As the size of the particles increases the total surface

10. Howe, Proc. A. S. T. M., 17, II, 5-8 (1917).
11. Sauveur, The Metallography and Heat Treatment of Iron and Steel, p. 463.
12. Honda, C. A. 14, p. 3629 (1920) reports the heat of transformation of austenite to martensite to be 4.2 calories for 0.80 per cent carbon steel.

would decrease, and likewise the volume occupied by these particles. These changes would seem to account for the softening of the steel and for the removal of internal stresses.

As this drawing temperature is increased, the particles that first appear are very fine and can hardly be distinguished as separate phases under the microscope, as shown in Fig. 3. Depending somewhat upon the size of these particles and their appearance under the microscope, steels have been classified as troostitic, sorbitic, etc. To take the most extreme case in the growth of these particles, we have granular pearlite which can be obtained by a long-continued drawing process at the temperature just below the lower critical, as shown in Fig. 1. Here the carbide particles collect in large size so that they can be observed and identified at relatively low magnifications. They are rounded and therefore approach the minimum surface and the minimum volume for that size of particle. This results naturally in a very soft form of steel.

Influence of Alloying Elements. The influence of alloying elements seems to be primarily to change the rate of solution and precipitation, and finally the rate of collection of small particles into large ones. It seems that the various properties of alloy steels can be explained with considerable satisfaction from this point of view. Alloying elements may associate themselves with the carbide, with the pure iron, or with both. For example, the chromium and tungsten elements are supposed to be associated principally with the carbide; nickel and manganese, on the other hand, are more inclined to be with the iron. However, in either case this alloying element will influence the rate at which solution will take place on heating an annealed steel. It may make it go into solution at lower temperature, as is the case with nickel and manganese steels, or it may go into solution at higher temperature as in the case of chrome and tungsten steels. Having obtained a perfect solution of these steels, when they are quenched the precipitation takes place more readily or less readily than in a straight carbon steel. Thus the alloying elements in steels are probably more easily understood if they are considered as catalysts which accelerate or retard the rate of solution and precipitation of the carbides.

Hardening of Nonferrous Alloys. Phenomena similar to those discussed above have been observed in the heat treatment of nonferrous alloys. The nonferrous alloy which has attracted most attention, because of the fact that it can be heat treated, is doubtless duralumin[13]. This alloy contains copper about 3½ per cent, manganese 0.5 per cent, magnesium 0.5 per cent, iron and silicon about 0.25 per cent each, and the balance aluminum. Copper and aluminum form an intermetallic compound, $CuAl_2$, which has its maximum solubility at about 540 degrees Cent., which solubility is about 4 per cent copper and decreases to probably 1 per cent at ordinary temperatures. This alloy, as is well known, is heat treated by heating almost to the region of maximum solubility, quenching and then aging. Quenching in this particular case does not seem to retain the alloy in the metastable condition at ordinary temperatures but permits it to go into the instable condition so that precipitation begins and gradually continues at ordinary temperatures. However, there is observed a heat evolution on reheating the quenched alloys to 250 to 275 degrees Cent. according to Merica and his co-workers. This precipitation results in an increase in the hardness and tensile strength. The

13. A comprehensive discussion of the heat treatment of duralumin is contained in Sci. Paper U. S. Bureau of Standards, No. 347, by Merica, Waltenberg and Scott.

rate of precipitation, or aging, at ordinary temperatures is much slower than it is if elevated temperatures are used. Thus having obtained the instable condition, the rate of precipitation is accelerated if an elevated temperature is used, but if too high temperature is used, there is a decrease in strength. Presumably as higher and higher temperatures are used there is first obtained a condition which approaches complete precipitation, which would give the maximum strength for a particular alloy, and then there would result a collection of the fine particles into large ones with a decrease in the surface of the precipitated particles and a decrease in their volume, with the result that there follows a decrease in the hardness of the heat treated alloy and also a decrease in its tensile strength. Apparently that balance between these two reactions which gives the maximum hardness is the condition which has recently been termed "critical dispersion" by Jeffries and Archer.[14] as it appears to the author the maximum hardness should represent maximum precipitation with minimum size of the precipitated particles. There is some evidence to indicate that similar conditions are observed in the case of steel. For example, the writer has had experience with hardened eutectoid steel which showed much greater plasticity immediately after quenching than it did after a draw at temperatures as high as 450 degrees Cent. for a period of one hour. Commercially, the binary alloy of copper and aluminum is not hardened by heat treatment. Instead of that, use is made of an alloy to which has been added small percentages of manganese, magnesium, and in some cases calcium. This more complicated alloy seems to correspond to our alloy steels, and the function of the element, such as manganese, magnesium and calcium, is principally that of a catalyst with reference to the rate of solution and precipitation.

Another illustration of the heat treatment of nonferrous alloys is found in the alloys of magnesium and aluminum. The exact nature of the intermetallic compound formed in the aluminum-rich alloys is not as well established as in the case of the copper-aluminum alloys. Merica, Waltenberg and Freeman[15] concluded that the intermetallic compound was Mg_4Al_3 and determined its solubility in the region between the eutectic point 450 and 300 degrees Cent. They found a homogeneous structure with 12.2 per cent magnesium at 450 degrees Cent., but a duplex structure with 5.9 per cent magnesium after annealing at 300 degrees Cent. This indicates a decrease of over 50 per cent in the solubility through a range of 150 degrees Cent. In a somewhat more recent publication by Hanson and Gayler[16] the authors find about the same solubility at 448 degrees Cent., but a considerably greater solubility at 300 degrees Cent. They also concluded that the intermetallic compound is Al_3Mg_2 instead of Mg_4Al_3. Regardless of which of these is the correct formula for the solute, there seems to be no question but that it is an intermetallic compound dissolved in aluminum. The alloys of this system which are rich in magnesium are also solid solutions and Hanson and Gayler have assigned to the solute the formula Al_2Mg_3. Alloys of this type containing about 8 per cent of aluminum have been developed commercially and respond to heat treatment. In both of these cases complex alloys containing small amounts of metals such as calcium would seem to correspond to alloy steels and presumably increase the effectiveness of heat treatment.

While a general use has been made of the alloying elements in the steel

14. The Slip Interference Theory of the Hardening of Metals, Chem. & Met. Eng. 24, p. 1061 (1921).
15. Scient. Paper, U. S. Bureau Standards, No. 237, p. 113, 1919.
16. J. Inst. Metals, vol. 24, No. 2, p. 201 (1920).

industries, such elements as manganese, nickel, cobalt, chromium, molybdenum, tungsten, vanadium, uranium, having been used, it does not seem that their influence on the rate of precipitation and solution has been sufficiently emphasized. This relation stands out more prominently in the nonferrous metals in which the effect of heat treatment is greatly increased by the presence of a small amount of some of these elements which prevent or retard precipitation on cooling.

In the examples cited, it appears that hardening is obtained by first dissolving an intermetallic compound to produce a solid solution, quenching at such a rate that the compound is retained in the metastable condition, and later carried into the instable condition where precipitation takes place by cooling to lower temperatures or heating; or this same result may be obtained by a quenching at such a rate that the product obtained at ordinary temperature is in the instable condition so that precipitation gradually takes place, resulting in aging at ordinary temperatures or accelerated aging if slightly elevated temperatures are used.

Theories recently advanced by Rosenhain[17] and by Jeffries and Archer[18] with reference to the hardness of metals and alloys, have an interesting bearing on the heat treatment of alloys. The theory advanced by Rosenhain for the hardness of solid solutions seems to apply particularly to increasing hardness of alloys by the introduction of solute atoms into the space-lattices of the solvent. This relation the author states as follows: "The hardening effect of one metal upon another in the form of a solid solution should, to a first approximation, be inversely proportional to its solid solubility." In other words, the hardness in solid solutions is a function of the degree of saturation.

To account for the hardness in heat treated alloys by this theory, it is necessary to have a high degree of saturation. For example, martensitic steel would be a highly saturated solid solution; the change from austenite to martensite need only to involve a change in the degree of saturation. This change in saturation might be due to difference in the solubility of the solute at different temperatures, or to the formation of a new solute, as for example the formation of iron carbide from carbon and iron atoms, which has a markedly different solubility. On the other hand, the theory advanced by Jeffries and Archer seems to apply particularly to the hardening of alloys by a heat treatment in which the maximum hardness is due to a certain "critical dispersion" of precipitated particles. By this theory martensitic steel would be a hetrogeneous system in which the carbide is in the precipitated condition instead of being a solid solution.

If these general principles apply to the hardening of alloys, then we may speculate somewhat as to the future possibilities of the heat treatment of both ferrous and nonferrous alloys. First, it would be necessary to have a condition, or a system, in which there exists a solid solution having a difference in its saturation at different temperatures. The greater this difference in saturation the greater the possible effects of heat treatment. Those systems in which the solute is an intermetallic compound seem to offer the greater opportunities. Quenching would have to be accomplished by heating to a temperature such that the solute would be in solution, and then cooling at such a rate that the solution would be retained at ordinary temperatures with an increase in the saturation, or it would be retained in the instable

17. The Hardness of Solid Solutions, Chem. Met. Eng. 25, p. 243 (1921).
18. Loc cit.

condition so that precipitation would gradually take place. If the desired results cannot be obtained by the avaliable methods of cooling, then the next step would be to find some catalytic agent which would retard, or possibly prevent, the precipitation of the solute.

This idea opens up an unlimited field for investigation. As an illustration, the alloys of aluminum and iron at the present time are supposed to be worthless commercially; however, they form an intermetallic compound and if a catalyst could be found which would make it possible to retain this intermetallic compound in solution at ordinary temperatures and then have it precipitated, an alloy of great commercial value might be obtained. The possible combinations with the metals now available is practically unlimited. Researches along these lines may be expected to give good rewards, both to the researcher and to industry.

1921

THE CARBONIZING OF CAST STEEL PARTS

By William G. Conner

MANY objections are made to the use of carbonized cast steel parts because by construction these parts are porous and dense in spots, causing them to distort or warp in hardening after carbonizing. Many manufacturers claim to get good results by carbonizing and dipping or quenching the castingly directly from the carbonizing pots. This may be good practice for small parts but in carbonizing large gears or clutches, which are very difficult to handle at high temperatures, the author finds it unsatisfactory to try quenching at that period. All parts or pieces should be cooled in pots to atmospheric temperature, in fact slightly above this point will not prove detrimental, except in the case of cold rolled steel which can be carbonized and quenched directly from pots at carbonizing temperature. A nice refined case will be the result.

In packing cast steel the heat treater should use the same method as in carbonizing any other vanadium and alloy steel, using a pot large enough to allow sufficient carbonizing material to be packed between the inside of pot and all work or pieces. The writer finds that a good grade of carbonizer, not too fine, about ¼-inch in size that will pass through ¼-inch mesh screen is satisfactory as too fine a carbonizer becomes so tightly packed that it causes a longer time for heat penetration. These pieces vary greatly in carbon content; from as low as 12 to 15 per cent to as high as 25 to 30 per cent carbon. After this treatment many gear teeth when fractured showed a good deep penetration, 1/16 to 7/64 inch deep, and had a fairly refined case, at least as refined as one could expect with cast steel. Better results are obtained by annealing either before machining or after rough machining to see that the steel is usable.

Some hardeners tabulate their carbonizing furnace time from the moment the pots are entered into the furnace until they are removed, but that method is deceiving. The time should be tabulated from the time the pots and contents reach the desired carbonizing heat. For that reason the furnace is heated up to 1550 or 1600 degrees Fahr. before loading. That is, in the evening after the day's run the pots are all packed and sealed, and the furnace reloaded thus leaving the pots in the hot furnace over night to absorb the heat. By 7 a. m. the pots or pyrometer reading will be 1000 to 1200 degrees Fahr., depending upon the load and amount of heat in the furnace when loaded. This insures an early or much more prompt carbonizing heat throughout the pots and furnace. By 10:30 a. m. the temperature easily reaches 1675 or 1700 degrees Fahr. after which it is readily maintained at a 1700 degrees Fahr. temperature throughout the day or until 5:30 p. m., at which time, after taking out the day's heat to normalize or cool down in pots, another load is ready to be carbonized.

For hardening these large cast steel gears and other parts special tongs have been made which grip the gears well over the teeth or face and in toward the center of gear web or spokes, so as not to interfere with the teeth in any way. By using a rope, tackle, and swinging jib

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A paper prepared for for the Philadelphia Convention. The author, William G. Conner is foreman of the hardening room, George D. Whitcomb Mfg. Co., Rochelle, Ill.

crane the gears are placed over the quenching tank and lowered to the required depth vertically into a good grade of quenching oil. When they are removed still warm they are plunged into a clear cold water bath which tends to crack off or loosen the black film that collects from the oil bath. This leaves the parts fairly clean.

For hardening cast steel the heat usually is brought up gradually to 1440 or 1450 degrees Fahr. for the oil bath, and in dipping by the method just outlined there has been no complaint from the gears warping. They come out true and straight, with a good wearing surface on the teeth and hardened, with a case penetration of about 1/16 inch or better.

OBITUARY

JOSEPH WILLIAM RICHARDS

JOSEPH WILLIAM RICHARDS, professor of metallurgy at Lehigh University, South Bethlehem, Pa., for 30 years and a well-known member of the American Society for Steel Treating, died suddenly of heart disease at his home in Bethlehem, Pa., Oct. 12. He was 57 years old, having been born July 28, 1864, in Oldbury, England. He was internationally known as a metallurgical and chemical engineer and for his expert advice in litigation involving questions of metallurgy. At the time of his death, Doctor Richards was secretary of the American Electrochemical Society, a position which he held for many years. Professor Richards was the first president of the American Electrochemical Society and at one time was vice president of the American Chemical Society and a member of its council.

His early education was completed in Philadelphia high school from where he went to Lehigh, taking the chemical course and graduating in 1886. Later he studied in Heidelberg and Freiberg universities, Germany. In 1897 he was appointed a member of the United States Assay Commission and in the same year was made president of the chemical section of Franklin Institute, Philadelphia. He represented the institute at the International Geological Congress in Russia that year and two years later was made a member of the jury of awards in the chemical division of the National Export exhibition at Philadelphia. He served in a similar capacity at the Panama-Pacific exposition in 1915. For three years to 1918, Doctor Richards was a member of the United States Naval Conservatory Board.

Doctor Richards was the author of Aluminum; Metallurgical Calculations, Part I; General Metallurgy, Part II; and Iron and Steel; articles on metallurgy in Chandler's encyclopedia and many contributions to scientific journals. He translated Electrolysis of Water; Electrometallurgy in Chromium; Arrangement of Electrolytic Laboratories; and Electrolytic Production of Metallic Objects. In addition to the American Society for Steel Treating and the American Electrochemical and the American Chemical societies, Doctor Richards was a member of the Faraday Society, the Deutsche Bunsen Gesellschaft, the American Institute of Mining and Metallurgical Engineers, the American Iron and Steel institute and other technical societies.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

ANDERSON, ERNEST L., (M-9), 21 Hull St., Jamestown, N. Y.
AVON, ARTHUR J., (M-10), 548 Jackson Ave., Jersey City, N. J.
BATHGATE, O. H., (M-8), Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
BELL & GOSSETT CO., (S-10), 117 N. Dearborn St., Chicago, Ill.
CASE HARDENING SERVICE CO., (S-10), 2282 Scranton Rd., Cleveland, Ohio.
EMORY, W. C., (M-10), Witherow Steel Co., Pittsburgh, Pa.
FALES, HERBERT G., (M-6), 145 Highland St., W. Newton, Mass.
GREENHALGH, W. H., (M-10), 2648 N. 17th St., Philadelphia, Pa.
HERR, BENJ. M., (A-9), 701 Federal Reserve Bldg., Pittsburgh, Pa.
HOLMES, J. Q., (M-9), Nordyke & Mormon Co., Indianapolis, Ind.
HURLEY, W. B., (M-2), Dodge Bros., Detroit, Mich.
IRVIN, E. H., (M-10), 1607 Summer St., Philadelphia, Pa.
KENNEDY, WM. M., (M-10), Park Steel Works, 30th and Smallman Sts., Pittsburgh, Pa.
LANNON, JOHN D., (M-9), 389 Tuxedo Ave., Detroit, Mich.
LEKBERG, C. H., (M-8), 9814 Avenue H, Chicago, Ill.
LIGHT, CYRIL H., (M-10), Rm. 325, 122 S. Michigan Ave., Chicago, Ill.
MICHIGAN AGRICULTURAL COLLEGE, (Sb.-1), Library Dept., No. 3023 East Lansing, Mich.
MOORE, F. GUY, (M-9), 54 Chestnut St., Jamestown, N. Y.
NIMICK, T. HOWE, (M-10), Colonial Steel Co., Keystone Bldg., Pittsburgh, Pa.
PASMORE, E. H., (A-9), Columbia Tool Steel Co., 552 W. Lake St., Chicago, Ill.
PENFIELD, EARLE A., (M-9), Frasse Steel Works, Inc., Hartford, Conn.
POLE, EDWARD, (M-10), 8 Sharon St., Geneva, N. Y.
RIES, E. F., (M-10), Harrison Pike, Sta. L, P. O. Box No. 25, Cincinnati, Ohio.
ROSS, ERLE F., (M-10), The Iron Trade Review, Cleveland, Ohio.
SCHMITT, FRANK, (M-9), 811 W. Lafayette Blvd., Detroit, Mich.
SCHUMACKER, IRWIN C., (A-9), Midvale Steel & Ordnance Co., McCormick Bldg., Chicago, Ill.
STEWART, P. E., (M-9), Transue & Williams Steel Forging Co., Alliance, Ohio.
STUBING, A. F., (M-10), care Railway Mechanical Engr., 232 Broadway, New York City.
THOMSON, W G. H., (M-10), 1455 West 37th St., Chicago, Ill.
THORPE, S. T., (M-10), Horton Mfg. Co., Bristol, Conn.
TRAVIS, CHARLES, (M-9), 718 18th St., Rock Island, Ill.
TREADWAY, T. G., (M-10), Horton Mfg. Co., Bristol, Conn.
WOOD, EDSON, (M-9), 315 Bay St., Springfield, Mass.

CHANGES OF ADDRESS

ALBERS, L., JR. from 95 Brandt Place, New York City, to 175 Bleecher St., Brooklyn, N. Y.
AVERY, JAMES H.—from 257 W. Exchange St., Providence, R. I., to National Ring Traveler Co., P. O. Box 1256, Providence, R. I.
BOHNER, CARL M.—from 652 Market St., to 357 E. Buchtel Ave., Akron, Ohio.
BRANIGAN, PAUL J.—from 131 College Place, to 447 S. Beech St., Syracuse, N. Y.
COOPER, CHAS. H.—from North East Elec. Co., Rochester, N. Y., to Philmont, New York.
DICKSON, LIEUT. T. C.—from U. S. Ordnance Dept., Watertown Arsenal, Watertown, Mass., to the University Club, Golden Hill Rd., Bridgeport, Conn.
DIEDERICHS, WM. J.—from Timken Roller Bearing Co., Columbus, Ohio, to 1027 Lincoln Way, Ames, Iowa.
FARNSWORTH, GROVER,—from Oakland Motor Car Co., Pontiac, Mich., to 2981 East Grand Blvd., Detroit, Mich.
GEPHART, H. O.—from 600 George St. to 57 Whalley Ave., New Haven, Conn.

GILMOUR, M. L.—from 406 Hennepin Ave., Dixon, Ill., to 316 McKinney Ave., Houston, Texas.
GOSZTONYI, V. A.—from 1714 Quarrier St. to 3 Curry St., Armor Park, South Charleston, W. Va.
HARDER, PROF. OSCAR E.—from University of Minnesota to 707 University Ave. S. E., Minneapolis, Minn.
HAYDOCK, JOHN JR.—from Niles-Bement-Pond Co., Plainfield, N. J., to 111 Broadway, New York City.
HAYWARD, HENRY E.—from Link Belt Co., Dodge Plant, to 1835 N. Delaware Ave., Indianapolis, Ind.
HOLSBERG, W. A.—from 112 Clybourn St., Milwaukee, Wis., to 107 Sheffield Ave., Buffalo, N. Y.
HULBERT, L. G.—from Hares Motors, Inc., Bridgeport, Conn., to 4524 Avery Ave., Detroit, Mich.
JOSEPH, CARL F.—from 4845 Concord to 7420 Third Ave., Detroit, Mich.
KENNEDY, M. W.—from 2031 E. Dauphin St. to 5013 Smedley Ave., Philadelphia, Pa.
KRUGER, LOUIS R.—from 4622 N. Racine Ave. to 4522 N. Magnolia Ave., Chicago, Ill.
LARDNER, JAMES F.—from 723 20th St., Rock Island, Ill., to Y. M. C. A. Moline, Ill.
LARNED, LIEUT ELMER—from 6341 Kimbark Ave. to Interstate Iron & Steel Co., East Chicago, Ind.
MAROT, EDW. H.—from Steel Treating Equip. Co., 7939 Lafayette Blvd., to 2301 West Euclid Ave., Detroit, Mich.
McANIFFE, HUGH F.—from Moores-Philadelphia to Holmes, Del. County, Pa.
REICHHELM, P. R.—from American Gas Furn. Co., to American Swiss File & Tool Co., 24-26 John St., N. Y. C.
RICHARDS, W L.—from 1128 Stratford Ave., Stratford, Conn., to 89 Chatham St., New Haven, Conn.
ROBERTS, LAWRENCE J.—from 1287 Military Ave. to 1309 Military Ave., Detroit, Mich.
ROSEN, JOE—from Troy Foundry Mach. Co., Chicago, Ill., to Harms Hotel, Rock Island, Ill.
VAN AUSDALE, JOHN S.—from 1908 Harrison St. to 1912 Harrison St., Davenport, Iowa.
WHITE, FRANCIS GUY—from 10 Portland Place to North Side Y. M. C. A., Grand and Sullivan Aves., St. Louis, Mo.
WOLNICK, H. F.—from 2502 Eastwood Ave. to 2231 San Jose Ave., Chicago, Ill.

MAIL RETURNED

EVANS, H. J., Ridge and 14th Ave., New Kensington, Pa.
HORN, S. C., (M-10), Wilson Maeulin Co., P. O. Box 1351, Pittsburgh, Pa.
HURLEY, WM. B., 2985 West Blvd., Detroit, Mich.
SMITH, HENRY BOYNTON, New Britain Machine Co., New Britain, Conn.

News of the Chapters

METALLURGY COURSE MAKES FLYING START

By Paul C. Tris

JOHN F. KELLER

EVENING courses in metallurgy inaugurated in 1920, at Lewis Institute, Chicago, by the Chicago Chapter of the American Society for Steel Treating, swing into their second year with greatly increased momentum. Most of the credit for the success of these courses must be given Prof. John F. Keller, formerly of Purdue University, Lafayette, Ind., who was national president of the Steel Treating Research Society, which combined with the American Steel Treaters Society in 1920 to form the present great national organization.

In fifteen years of instructional work in forging at Purdue University, Professor Keller has gathered a prodigious number of lantern slides illustrating every step in the manufacture, treating, and handling of steel and iron in all its forms and variations. Lectures which occupy only a small part of the course in comparison with the time spent in actual work done by the students, are thus enlivened with an interest far beyond the usual. This year films are being used.

The following announcement was sent out recently to all firms having representatives in the membership of the American Society for Steel Treating:

ANNOUNCEMENT

"HEAT TREATING OF IRON AND STEEL"
"METALLOGRAPHY OF IRON AND STEEL"

Lewis Institute offers the above courses to a limited number of students, in evening classes of 15 weeks, two evenings a week.

The courses are open to students and industrial employes who have had practical experience or preparation; such as, Blacksmiths, Tool Hardeners, Tool Makers, Foremen, Superintendents, Heat Treaters, Metallurgists, Chemists, Inspectors, Salesmen.

Classes are limited to size and all enrolling after the quota is filled will be placed in classes to follow.

Classes in "Heat Treatment of Iron and Steel" meet Monday and Wednesday, 6:20 to 9:40 p. m., beginning Oct. 10, 1921.

Classes in "Metallography of Iron and Steel" meet Tuesday and Thursday, 6:20 to 9:40 p. m., beginning Oct. 11, 1921.

Tuition fee $20.00 for each course, payable in advance.

For further information call or write, Lewis Institute, 1930 West Madison Street, Chicago, Ill.

A synopsis of the course was also enclosed as follows:

COURSE 3-B—HEAT TREATMENT

1—Manufacturing methods—ore to finished product.
2—Methods of determining grades. The spark method.
3—Crystalline structures—Effect of heat and mechanical working on the structures of iron and steel.
4—Pyrometry—Various methods of measuring temperature.
5—Critical temperatures—Methods of Determination.
6—Forging—Theory and fundamental—The effect of improper methods.

FIG. 1—SOME OF THE EQUIPMENT IN THE HEAT TREATING DEPARTMENT OF LEWIS INSTITUTE, CHICAGO

7—Annealing and normalizing.
8—Hardening and Strengthening—Proper methods for obtaining certain physical properties.
9—Quenching—Methods and mediums.
10—Warping and cracking—Reasons and preventative methods.
11—Testing—For hardness and physical properties.
12—Tempering—Methods and procedure.
13—Special steels—Heat treatment.
14—Illustrated lectures and demonstrations on the "Uses of Metallography."
15—Methods of case hardening and the various heat treatments—Selective hardness.
16—Exercises in the above phases of the work will be included in the course given students in the forge and heat treatment department.

The equipment of the heat treating department as shown in the accompanying illustration, Fig. 1, is all new and as complete as it is possible to procure. Shown from left to right in this illustration are the lead

pot, oil drawing furnace cyanide pot, muffle furnace, high speed furnace, large tool or small die furnace, a three temperature high speed furnace, large carburizing or hardening furnace and an electrical resistance type furnace. These furnaces are all equipped with pyrometers connected in series with recording instruments, while the electric furnace, shown more in detail in Fig. 2, has a recording instrument for obtaining graphic heating curves and critical temperature charts. The entire heat treating department is located in the forge shop, where unequalled facilities are provided for forming and fabricating the tools for hardening and tempering by the students. Classes as large as can be handled have here full equipment for actually undertaking any process of tool making or of heat treatment.

The course in metallography aims to remove the usual objections of plant managers and superintendents that their metallographists are unable to diagnosis their photomicrographs. The course in heat treating and metallography being conducted simultaneously renders the course of special benefit as to actual work. The course is as follows:

COURSE 3-D—METALLOGRAPHY

To meet the demand for scientific information concerning the microstructure of metals, Lewis Institute is offering an evening course in the principles of metallography as applied to the investigation of iron and steel.

This course will embrace a study of carbon steel, tool steel, high speed, alloy steels, cast iron, and wrought iron. Photomicrographs will be made of many of the specimens. Students will perform all work in connection with the preparations of the samples, exactly as done in commercial laboratory practice.

This work will be of great value to chemists, inspectors, heat treaters, steel salesmen; or in fact to anyone connected with the metal industry.

1—Pure Metals—Their structure.
2—Longitudinal and transverse sections.
3—Grain size.
4—Quenching effects on manganese steels.
5—Quenching effects on high carbon steels.
6—Drawing effects on high carbon steels.
7—Effects of heat treating tool steels.
8—Etching solutions on high carbon.
9—Case hardening.
10—Effects of overheating.
11—Drawing high speed steel.
12—Effects of cold working on steel.
13—Examination for phosphorus and sulphur.

A horizontal metallographic outfit of the newest type made by the Bausch & Lomb Optical Co., Rochester, N. Y., and taking up to 8 x 10-inch negatives at magnifications of from 25 to 1000 diameters is used. The motor driven polishing table will accommodate eight students, the polishing heads having interchangeable disks. The school is also provided with tensile, torsional and hardness testing machines of the latest type and highest capacity.

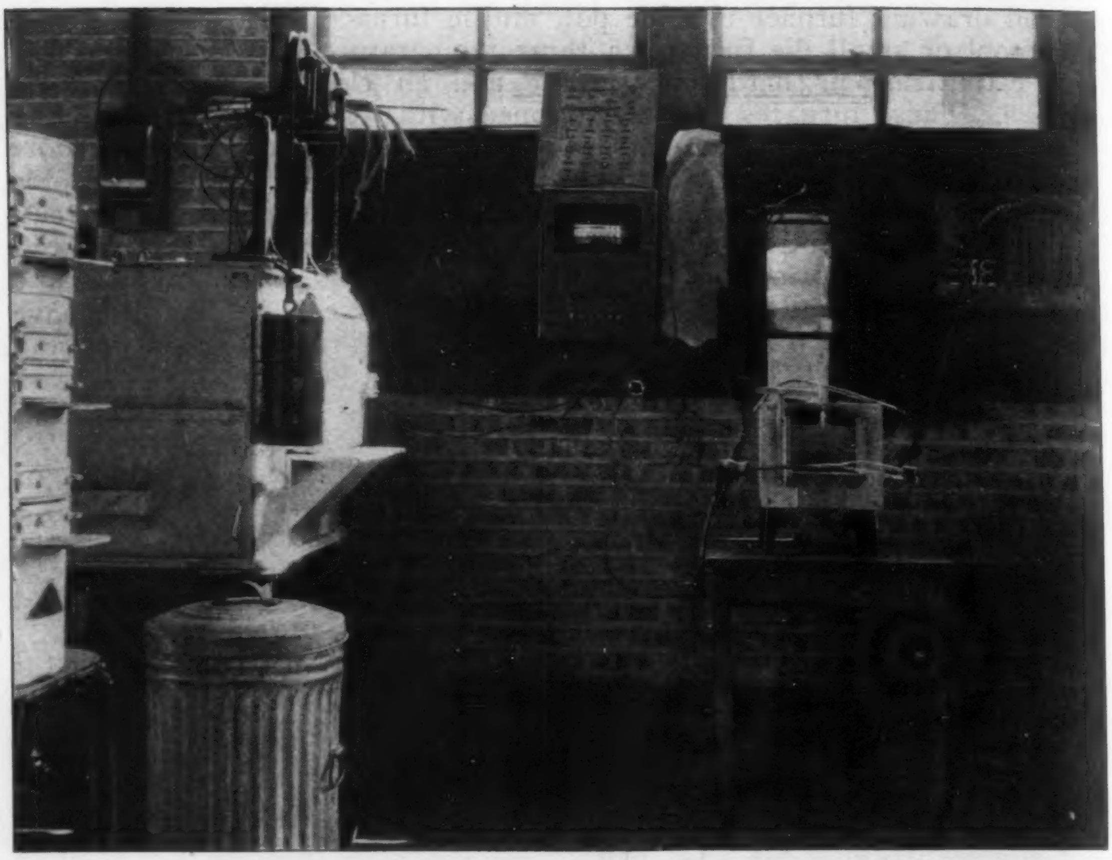

FIG. 2—THE ELECTRIC FURNACE AND RECORDING INSTRUMENT FOR OBTAINING GRAPHIC HEATING CURVES AND CRITICAL TEMPERATURE CHARTS

Judging from last year's experience and this year's flying start there is little doubt but that Lewis Institute will enable many men to become expert metallurgical workers.

PROVIDENCE CHAPTER

The Rhode Island chapter held its first meeting of the 1921-1922 season on Wednesday, Oct. 5, in the rooms of the Providence Engineering Society. K. A. Juthe, American Metallurgical Corp., Boston, presented a very fine paper. At the close of the paper an interesting discussion followed. It was announced that all future meetings will be held on the first Wednesday of each month, and talks will be presented upon the manufacture and treatment of steel.

WORCESTER CHAPTER

The Worcester Chapter of the American Society for Steel Treating met on Oct. 13 at the National Metal Trades Association rooms, Worcester, Mass. Wheaton B. Byers, President of the New England Metallurgical Corp., formerly assistant metallurgist at the Watertown Arsenal, delivered a paper on "Carburizing". The paper covered the history, theory, and modern practice in carburizing.

A very lively discussion followed the paper, in which all the members participated. Visitors were present from Boston, Springfield, and Provi-

dence chapters, and expressed the feeling that the Worcester organization was a very live number.

The Executive Committee of the Chapter met on Oct. 5, and it was decided that the Chapter shortly would institute a class in elementary metallurgy and metallography as applied to iron and steel. V. E. Hillman, Chairman of the Worcester Chapter, has volunteered his services, inasmuch as he has had experience prior to this and conducted classes of this nature. His lectures are all prepared and the fee of $5.00 will be charged for members. No one will be admitted to the course except members.

A big increase in membership is expected before our next meeting.

Chairman Hillman at the opening of the meeting spoke as follows:

"Before the principal speaker of the evening is introduced, I wish to make a few brief remarks regarding the policy of the Worcester Chapter for the ensuing year.

"Your Executive Committee will make every effort to present subjects which are of a practical nature, subjects which you will be able to digest, subjects which are not shackled with deep theory. There appears to be some divergence of opinion, however, as to the best plan of procedure to follow when the various chapters of the National Organization are in session.

"Personally, I firmly believe that each Chairman is confronted with a proposition that is a case unto itself. Conditions and influences vary in different sections of the country. Ways and means which are applicable to one chapter may be wholly unfit for another. Therefore, it is incumbent upon each chairman to cater to the whims and fancies of his constituents. If the members are not interested in the relationship which exists between cause and effect—discard the theory and impress upon the gentleman who is reading the paper the necessity of refraining from the use of such words as exfoliation, pseudo-martensite, and intergranular eutectic.

"Very few speakers are capable of imparting theoretical knowledge in a clear and concise manner. Many technical men are wont to use Latin and Greek terms. They shun the simple Anglo-Saxon word which carries weight, power, and conviction. What is the result? The audience easily loses the train of thought, the continuity of the discourse is broken, and the evening is stigmatized as being too theoretical, and beyond the grasp of the layman, who is equipped only with a grammar school education.

"Some of you gentlemen may feel that you are technical men, college bred, and capable of understanding Bielby's amorphous theory, the Widmanstaten structure, the mechanism of hardening, transformation points, etc.,—granted. But if we depend upon the technical men to keep the National Organization intact, our growth will be stunted. We will suffer decay, and eventually perish. We must cater to the masses, to the hardening room foreman, who has a vague conception of a solid solution; to the executive, who does not want to have his mind irritated by a pedantic metallurgist.

"Therefore, I shall summarize my remarks by stating first that this Chapter will function in accordance with the demands made upon it; secondly, the audience will be anticipated; thirdly, we propose to direct our appeal to the masses—the 'Men at the Fire.'"

The executive meeting of the Worcester Chapter on Oct. 5 decided

on the following form or procedure for the ensuing year, and it is explained by the copy of the following letter sent to superintendents of firms in Worcester and vicinity:

"The Executive Committee, Worcester Chapter of the American Society for Steel Treating convened Oct. 5 for the purpose of discussing a plan of procedure for the ensuing year.

"In addition to the regular monthly meetings, the Chapter decided to conduct a series of 15 lectures pertaining to the Metallurgy of Iron and Steel. An outline of the course is subjoined below.

Iron ores
Blast furnace
Acid open-hearth furnace
Basic open-hearth furnace
Bessemer steel
Electric steel
Fluxes
Ferroalloys
Various grades of steel
The elements: Sulphur, phosphorus, manganese, carbon, chromium, nickel, tungsten, vanadium.
Hardening, drawing, annealing, carburizing
Recalescence and decalescence points
Microphotographs and their practical application
Complete discussion of:
- Pearlite
- Martensite
- Troostite
- Sorbite
- Ferrite

Wrought iron:
- Slag fibers
- Transverse section
- Longitudinal section
- Segregation

Cast and malleable iron:
- Cementite
- Graphitic carbon
- The Brinell machine
- The scleroscope
- The tensile strength testing machine
- The metallographic bench
- The heat treating furnaces
- The different quenching mediums
- The various drawing baths

"Only members of the Society are eligible to enroll in the class. A fee of five (5) dollars will be charged to cover the expenses incident to conducting the course.

"The Executive Committee is writing to inquire if you will notify the men in your plant who may be interested—foremen—subforemen, men in the heat treating department, salesmen, executives, tool makers, in fact, any one who is seeking a general knowledge of steel metallurgy.

The class will meet on either Tuesday or Thursday evening—time 7:00 to 8:15 p. m.—central location.

Address all communications to the Chairman of the Executive Committee, Commonwealth Club, State Mutual Building, Worcester, Mass."

TRI CITY CHAPTER

The Tri City Chapter held its meeting at the Davenport Chamber of Commerce on Thursday evening, Oct. 13. N. B. Hoffman, metallurgist of the Colonial Steel Co., presented a paper on the "Effect of Hot Rolling and Cold Drawing on Steel Wire". Dr. Hoffman is an authority on this

subject, as he has had wide experience in connection with the manufacture of steel, and his paper was very interesting to the large number in attendance.

CLEVELAND CHAPTER

The September meeting of the Cleveland chapter was held at the Cleveland Engineering Society's rooms on the mezzanine floor at Hotel Winton, on Friday evening, Oct. 30. An interesting paper was presented and discussed. Immediately following interesting reports of the Indianapolis Convention were received.

ROCHESTER CHAPTER

A well attended meeting was held on Tuesday, Oct. 4, at the Camera Works department, Dr. N. B. Hoffman, metallurgist of the Colonial Steel Co., presenting a very interesting paper covering matters of importance to everyone connected with the use, purchase or sale of steel. Dr. Hoffman's interesting paper was illustrated by lantern slides and most thoroughly appreciated.

CINCINNATI CHAPTER

The September meeting of the Cincinnati Chapter was held at the Ohio Mechanic Institute on Friday, Sept. 16. The speaker of the evening was Samuel Spaulding, of the Halcomb Steel Co., who presented an illustrated paper on alloy steel. The attendance was very satisfactory.

The regular October meeting was held at the Ohio Mechanic Institute at 8 P. M. on Friday, Oct. 21. A large number of members and friends were in attendance to hear a round table discussion of the Indianapolis Convention.

LEHIGH VALLEY CHAPTER

Lehigh Valley had its regular October meeting on Oct. 10 at the Board of Trade rooms at Easton, Pa. About 75 members and guests were in attendance. There were papers presented by S. S. Ball on "Ingots" and J. M. Sylvester on "Forging". The first meeting of the year proved to be a very interesting one and the discussion lively.

DETROIT CHAPTER

The first meeting of the year was held on Sept. 8 at the Board of Commerce building at 8 o'clock. Chairman Danse told of the plans concerning the affiliation of scientific societies in Detroit as well as plans for the Indianapolis Convention.

The Octōber meeting was held on Oct. 13. H. J. Lawson spoke on "The Origin and Aims of Our Society". Mr. Lawson was one of the charter members of the Society and spoke pleasingly and entertainingly with reference to it.

The second part of the meeting was devoted to the discussion of high nickel steels.

ST. LOUIS CHAPTER

The first meeting of the year was held at the American Annex Hotel on Monday evening, Sept. 12. A round table discussion took place after the dinner which was followed by an important business meeting.

The October meeting was held on Oct. 21 at the Engineers' Club, 3817 Olive street. The speaker of the evening was Maj. James W. Mills,

superintendent of the open-hearth department of the Enameling and Stamping Co. Major Mills has had many years of practical experience in the manufacture of carbon steel and was extremely well qualified to discuss this subject.

The members of the chapter were particularly interested in making St. Louis the Pittsburgh of the West, maintaining that they make excellent steel from Illinois coal and Missouri ore. After the paper of the evening, a very lively discussion took place on open-hearth practice.

A special announcement for the season of 1921-1922 for the St. Louis chapter was that they had decided to discontinue the dinners and to have a permanent meeting place and a fixed night. Arrangements have been made with the Engineers' Club to hold all of the meetings in its hall. Beginning with November, all of their meetings will be held on the first Friday before the first Monday of each month at 8 P. M. The November meeting will be held on Nov. 11, and the December meeting on Dec. 9.

CHICAGO CHAPTER

The October meeting of the Chicago Chapter was held at the City Club on Thursday, Oct. 13. Lt. Col. A. E. White, director of the department of engineering research of the University of Michigan and first National President of the American Society for Steel Treating was to have been present to present a paper on "Alloy Steels", but due to unavoidable conditions, Col. White could not be present and his paper was presented by Professor Upthegrove, of the University of Michigan. The paper was particularly well received and a very interesting discussion followed. About 125 were presented at the dinner.

The following important notice was sent to all members of the Chicago chapter:

"We are confident that every member of the Chicago Chapter of the American Society for Steel Treating wants to make this a big year for our chapter. We have the largest membership in the Society and we want the hearty co-operation of everyone to prove to the other chapters that Chicago is at the top in accomplishments as well as number of members. Start the year right by filling in the blanks on the attached card and attending our first meeting.

"Your executive committee wants your co-operation in making the coming meeting interesting and instructive to the very largest number of members possible. You can assist greatly by filling in the blank spaces with subjects or problems in which you are interested and would like to have discussed at one of our meetings.

"Your executive committee is very anxious to make all of our meetings of special interest to the practical and nontechnical members of our chapter and if possible to help them with their every day problems. We have made arrangements with the Chicago City club to hold all of our meetings there where we can secure the very best of accommodations for our members. Our meetings will be held on the second Thursday of each month. Be sure to reserve this date on your calendar for the upbuilding of the profession to which you belong. Outside speakers will present papers on alternate months and the other months will be taken up with practical discussions on our local problems. At these practical meetings we will have present men having exceptional experience in practical heat treating and metallurgy, so that all of our members can gain by their experience. We want you to bring your plant executives to all of our meetings. We want to show them that the results of our meetings mean dollars and cents in their pockets. Remember the meeting dates and all take an active part in the program for the coming year."

SCHENECTADY CHAPTER

A picnic was held on Sept. 15 at the Locomotive Club at 6 p. m. The members of the American Locomotive Co. challenged the General Electric Co. members to a baseball game and the challenge was accepted.

The name of the engineering professor who served as umpire was kept secret but even with all of these precautions it was impossible to determine which side won inasmuch as the score keeper went home after the first inning and took the score book with him.

Kid Nelson and Dick Murphy changed their quarters from Jersey City in order to put on an exhibition for the members.

A wrestling match between Pink Primmer and Slipper Alum resulted in a draw after a very high temperature had been reached. Both were immediately quenched in cold water.

The Executive Committee of the Schenectady chapter received a write-up in the Schenectady Gazette as follows:

"The executive committee of the Schenectady chapter, American Society for Steel Treating, selected the third Tuesday of each month for meetings. Meetings are to be held in Albany and Troy also. The Schenectady meetings will be held in the civil engineering building at Union college.

"An entertainment and papers committee was appointed to arrange programs for all regular meetings of the chapter. G. R. Brophy, metallurgist of the General Electric Co., was appointed chairman. Other members are J. L. McFarland, engineer, General Electric Co.; William L. Weaver, Ludlum Steel Co., Watervliet; P. A. Cuenot, engineer, and B. H. Magill, inspector, American Locomotive Co.

"A membership committee was also appointed, with L. F. Mulholland, assistant engineer of tests, American Locomotive Co., as chairman, aided by Enrique Touceda, consulting engineer, Albany; Benjamin Harmon, metallurgist, Watervliet arsenal; John B. Rice, electric furnace specialist and Richard Topham, tool treating department, General Electric Co.

"Schenectady chapter received honorable mention at the national convention of the society at Indianapolis this year. All meetings are open to the public. Talented speakers are engaged to deliver the lectures. The first regular meeting will be held October 18.

The regular October meeting which was held on Oct. 18 at the Union College Civil Engineering Building, had over 100 in attendance. A paper was presented by Dr. Willis R. Whitney, director of research of the General Electric Co., entitled, "Where Do We Go From Here?" Dr. Whitney handled his interesting subject in a very capable manner and it was thoroughly enjoyed by all present. H. H. Barker, Chief Chemist of the General Electric Co., gave a paper on "Radium Activity". Quite a number of entertaining numbers were held, consisting of singing, violin and piano selections.

MILWAUKEE CHAPTER

The September meeting was held at the Medford Hotel on Sept. 13, and the speaker of the evening was H. B. Knowlton, of the Milwaukee Continuation School, who presented a very capable paper on "Carburizing Materials."

The October meeting was held at the Medford on Tuesday Oct. 18, at 8 o'clock, preceded by a dinner at 6:30. The meeting was very largely attended, and interesting papers were presented by H. J. French, Bureau of Standards, on the subjects of "Some Effects of High Temperature on Steels" and the "Effects of Heat Treatment on the Mechanical Properties of Steel". The second part of the meeting was given to interesting reports of the Indianapolis Convention as well as to the discussion of molybdenum steel.

WASHINGTON CHAPTER

The October meeting was held in the auditorium of the New Interior Department building on Friday, Oct. 14. The subject in discussion was "High Speed Tool Steel".

In the absence of Secretary French, J. S. Vanick gave a brief outline of important events at the Indianapolis Convention. This was followed by the presentation of the paper on the "Constitution of High Speed Steel", by J. P. Gill, metallurgist for the Vanadium Alloys Steel Co.

The vigorous discussion which followed the presentation of the paper, revealed the interest of local members in the important problems relating to tool steel.

HARTFORD CHAPTER

The first meeting of the current season was held Thursday, Sept. 29, at the Hartford Electric Light Company's hall. Thirty-five members and guests attended. The meeting was addressed by Messrs. Gilligan, Gere, d'Arcambal, Moore and Stacks, who described different features they had observed at the National Convention. Mr. d'Arcambal also announced the program arranged for the remainder of the season.

Plans for increasing the membership of the chapter were discussed in connection with the New England area plan. Mr. Gere, Chairman, announced a plan to promote interest and discussion. At each meeting some member previously designated will be prepared to describe in detail some phenomenon or irregularity observed by him in his heat treating practice. It is hoped that this will stimulate discussion.

The first example of this was an irregularity observed in the heat treatment of ball bearing cones. These cones after a double treatment, namely, 1600 degrees Fahr. oil quench followed by a 1500 degree Fahr. oil quench, were tempered and tested with the file. The entire cone appeared file hard. After grinding the raceways, the ground surfaces were soft to the file. In order to reclaim them, the parts were requenched in oil from 1500 degrees Fahr. and tempered as before. The ground surfaces were still soft, whereas the remainder of the cone was file hard. Numerous experimental heat treatments were applied and examinations made to determine the reason for this phenomenon, but the only positive information developed was that the ground surfaces could be made file hard only by repeating the entire heat treatment, namely 1600 degrees Fahr. oil quench followed by 1500 degree Fahr. oil quench. If the 1600 degree Fahr. oil quench was omitted, soft raceways resulted.

Discussion of this phenomenon was lively, lasting for nearly half an hour.

The October meeting of the Hartford chapter was held in the Y. M. C. A. Assembly Hall on Thursday, Oct. 13. Professor John H. Nelson, of the Wyman-Gordon Co., presented the paper of the evening. About 105 were present.

Prof. Nelson's talk was illustrated with about 30 slides, covering design of crank forgings, defects in steel, and charts showing the variations in physical properties between steels of similar analyses made by different processes, also the effect of the drawing temperature on steels made by the different processes, as acid open-hearth, basic open-hearth, and electric furnace steels.

Discussion following his talk centered around "snow-flakes" and other defects in steel, "temper brittleness", and the relative merits of electric steels as compared with open-hearth.

NORTHWEST CHAPTER

The first meeting of the Northwest Chapter was held Friday night,

Oct. 14, at the Manufacturers' Club. There was the usual dinner at 6:30 with the program beginning at 7:30. The Northwest Chapter was fortunate in being able to secure H. J. French, of the United States Bureau of Standards, for this meeting. Mr. French discussed the mechanical properties of steels at various temperatures up to about 1200 degrees Fahr., and the effect of different heat treatments, and mechanical treatments, on the tensile strength, proportional limit, Brinell and Shore hardness, reduction of area, elongation, and impact toughness. We can most heartily recommend this address to any of the Chapters who can arrange to secure Mr. French.

A report of the committee in charge of the enrollment for the educational series of lectures showed an enrollment of about 30 at this time, and the committee expects this number to be increased to at least 50 by the time of the first lecture, Monday, Oct. 24.

SPRINGFIELD CHAPTER

The October meeting of the Springfield Chapter was held in the Chamber of Commerce rooms on Friday evening, Oct. 14. About 40 members and their friends were present.

Following a report by the Chairman on his visit to the Convention, a paper was read by Dr. Paul C. Doerr, New England representative of the Quacker Oil Product Co., on "Quenching and Tempering Oils, and Carburizing Materials." The paper, while covering a very broad field, was decidedly interesting and instructive. A good discussion followed.

PHILADELPHIA CHAPTER

A get-together meeing was held at the Engineers Club on Friday evening, Sept. 30. Reports from the Indianapolis Convention were received and J. L. DeMar, cartoonist for the Philadelphia Record, showed how he prepares his inimitable work.

The members did not have to bring their own smokes that night or sandwiches in their pocket, because the chapter had provided smokes and refreshments on tap.

The Philadelphia Chapter with the assistance of its capable Executive Committee has made arrangements with Temple University for a course in metallography during the coming year. An announcement and outline of the course are as follows:

To YOU who are interested in Steel, Greetings:

You well remember it was proposed that a course in Metallography be given under the auspices of the Philadelphia Chapter, American Society for Steel Treating, at Temple University. Enclosed please find an outline of the course.

Register at Temple University, Broad and Berks streets, at once. Mention the course to your friends and young men of your acquaintance who may be interested.

The Chicago Chapter of the Society gave a similar course last year, and it was a great success. The Philadelphia Chapter proposes to conduct a course at Temple University, which will be even more successful.

The course. The Course will be divided into two parts:

(a) Lecture Course. Thirty lectures, covering the process of manufacture, metallography, heat treatment, pyrometry and thermal analysis, physical and mechanical testing.

The lecture work may be taken without the laboratory work and will be made as clear, practical and elementary as possible. The lectures will be illustrated with experiments, lantern slides and films.

(b) Laboratory Course. Instruction in the laboratory will be made as practical as possible. The laboratory sections will be limited to twenty (20). The laboratory

will consist of instruction in practical shop methods. The work is so arranged that those having preliminary training may advance more rapidly than those having no preliminary training.

Instructors. Practical men, Members of the Philadelphia Chapter American Society for Steel Treating, and experts in their line.

Date of opening. Monday evening, October 3rd.

Time. Seven-thirty (7.30) p. m.

Place. Chemical Lecture Room, Temple University, Broad and Berks streets.

Fees. Lecture Course, $10.00. Laboratory Course, $25.00. Those who take the laboratory course are required to take the lecture course. Total cost of the course, $35.00.

Equipment. A complete equipment has been installed by Temple University for the course. Gas and electrical furnaces, grinding and polishing machines, microphotographic apparatus, pyrometers, etc.

Days on which work will be given. Lecture—Monday Evenings. Laboratory Work—Section 1, Tuesday and Thursday Evenings. Section 2, Wednesday and Friday Evenings. The opportunity is given to you. Enroll at once either for the lecture course or the complete course.

Sincerely yours,

TEMPLE UNIVERSITY AND THE EXECUTIVE COMMITTEE OF THE AMERICAN SOCIETY FOR STEEL TREATING

OUTLINE OF COURSE

I—GENERAL DISCUSSION OF IRON AND STEEL

1. Processes of manufacture. (a) Blast Furnace. (b) Wrought Iron. (c) Cast Iron. (d) Malleable Iron. (e) Bessemer. (f) Crucible Steel. (g) Open-Hearth Steel. (h) Electric Steel.
2. Rolling, Blooming, Cogging, Forging and Pressing, Drawing.

II—METALLOGRAPHY

1. Constitution Diagrams. 2. Use of Microscope. 3. Preparation of Specimens. 4. Structure of Iron and Steel.
   (a) Pure Iron. (b) Wrought Iron. (c) Low Carbon. (d) Medium Carbon. (e) High Carbon.

5: Effect of Impurities. 6. Structure of Cast Steel. 7. Effect of Mechanical Working on Cast Steel. 8. Structure of Cast Iron. 9. Case Hardening.

III—HEAT TREATMENT

1. General Purpose of Heat Treatment. 2. Discussions of Annealing, Hardening, Tempering and Case Hardening. 3. Heat Treatment of Carbon and Alloy Steels. 4. Miscellaneous Treatments.
   (a) Good. (b) Bad.
5. Fuel, furnaces and equipment.

IV—PYROMETRY AND THERMAL ANALYSIS

1. Temperature Scale. 2. Thermometers. 3. Thermocouples. 4. Resistance Thermometers. 5. Optical and Radiation Pyrometers. 6. Application of Pyrometers. 7. Thermal Analysis.
   (a) Time-temperature Curves. (b) Differential Curves. (c) Inverse Rate Curves.
8. Equipment Used in Thermal Analysis.

V—PHYSICAL AND MECHANICAL TESTING

1. Tensile Tests.
   (a) Tensile Strength. (b) Yield Point. (c) Proportional Limit. (d) Elastic Limit. (e) Elongation. (f) Reduction in Area.
2. Hardness Tests.
   (a) Brinell. (b) Shore, etc.
3. Impact Tests.
   (a) Charpy, Izod, etc.
4. Alternating Stress.

NEW YORK CHAPTER

The first meeting of the New York Chapter of the American Society for Steel Treating, in the regular series of monthly sessions for the 1921-1922 season, was held Wednesday evening, Oct. 19, at the Bush Terminal Sales Building, 132 West Forty-second street, New York. The chief speaker was Dr. John A. Mathews, president Crucible Steel Co. of

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America, who delivered a lecture on "Characteristics of Tool Steel, Mild Steel and Alloy Steel," illustrated with lantern slides. About 125 members were present.

For each monthly meeting the program committee of the chapter has selected a definite subject on which some well-known authority will speak. Besides the one for the October meeting, the following have been selected: November, "How Tool Steel Is Made; Comparison of Foreign and American Methods"; December, "What Happens to Steel When You Heat and Quench It?"; January, "Annealing and Tempering Machine and Tool Steels"; February, "Case Hardening, Ways of Doing It and What Happens"; March, "Treatment of High-Speed Steel"; April, "Hardening Room Troubles, Shrinkage, Warpage and Sealing"; May, "Up-to-Date Hardening Room Equipment Furnaces, etc."; June, "Spotting the Reason for Failures in Service." At each meeting there will be 10-minute talks on current events in the metallurgical world as published in the technical press.

Commercial Items of Interest

AS A result of many inquiries for metallurgical assistance in a research way, the Titanium Alloy Mfg. Co., Niagara Falls, N. Y., announces that it is arranging to offer to manufacturers and others interested in metallurgical and mechanical lines, the facilities of its physical laboratories equipped nine years ago. These laboratories which are comprised of four units—a testing laboratory, a metallographic laboratory, a room for experimental heat treating and a small experimental foundry—were equipped primarily for research and experimental work of an exacting nature, thus the apparatus is such as to insure accurate results.

Equipment is provided for most of the usual physical tests. Heat treating of any character can be done but only on an experimental scale. The experimental foundry is equipped only for work on metals which can be melted satisfactorily in crucibles. The metallographic laboratory is said to be one of the finest in the country and has produced highly satisfactory work. In the course of studying the effects of titanium on the many classes of steel, the company has handled steel of almost every grade and condition. The work of the metallurgical department has been to see these steels made properly and then to follow them through the laboratory, noting the causes and effects of their various peculiarities. Because of the impracticability for the average manufacturing plant to maintain a complete laboratory of its own, it is believed that many manufacturers will take advantage of the company's offer. Nominal charges will be made for services.

For quick and reliable hardness testing in the plant, the Case Hardening Service Co., 2284 Scranton road, Cleveland, is placing upon the market an auto punch which is virtually a Brinell tester in portable size. This device, which is shown in the company's advertisement on page 2, is of English origin, being manufactured by the Rudge-Whitworth Co., London. In operation a spring hammer in the barrel of the punch de-

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livers to a ¼-inch steel ball inside the cap at the bottom a blow of sufficient force to make a depression of 3 millimeters diameter or less according to the hardness of the test piece. A test is accomplished by gripping the knurled barrel of the punch and pressing down quickly until the spring hammer is released, driving the ball into the material under the test. The punch is made in two sizes, a 12-inch size and a 6-inch size for sheet brass and thin metals. With the device is furnished a table showing the relation between punch impressions and Brinell numbers.

Through error, Transactions failed to give credit for the preparation of "Tips for the Tool Hardener" which appeared on page 35 of the October issue. These suggestions, which are copyrighted, were written by Arthur G. Henry, special representative for the Vanadium Alloys Steel Co., with headquarters in the Chicago office. Mr. Henry has had wide experience in tool steel problems and is well known in this country and abroad. Coming as they do from a man with high rank as a metallurgist, these suggestions should be given most careful consideration.

A new instrument developed by the Stromberg Electric Co., Chicago, announces the completion of a process or operation by automatically operating a signal at the end of the predetermined time. Operating energy is secured from any convenient alternating current circuit. A glance at the dial shows the total length of the process, the length of time a process has been in operation and the length of time the process is to continue.

The Central Steel Co., Massillon, O., announces that the consolidation and merger of the Central Steel Co., the Massillon Rolling Mill Co., and the National Pressed Steel Co., all of Massillon, O., has been ratified by the stockholders of the three companies and became effective Aug. 18. In accordance with the agreement of consolidation, the Central Steel Co. assumed all the valid contracts and obligations of the other two companies. The new corporation, it is announced, takes the name of the Central Steel Co. and the following officers have been elected: Chairman of the board of directors and president, R. E. Bebb; first vice president, F. J. Griffiths; second vice president, C. C. Chase; third vice president, H. M. Naugle; secretary and treasurer, C. E. Stuart.

According to a recent announcement, an evening course in metallography and heat treatment of iron and steel will be given by H. M. Boylston and S. Z. Krumm, professor and instructor of metallurgy, respectively at Case School of Applied Science, Cleveland. Professor Boylston is well known in the metallurgical field and has been associated for many years with Prof. Albert Sauveur, of Harvard University. He is a member of the American Society for Steel Treating and during the past year has served as chairman of the Publication Committee. The course will begin Oct. 24 and will consist of 20 lessons over a period of 10 weeks, the classes being conducted from 7 to 10 p. m. on two nights of each week. The work will be done in the metallurgical laboratories of Case

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School of Applied Science, and the text book will be Sauveur's "Metallography and Heat Treatment of Steel." This is a similar course to one given at Case School last spring.

A thorough grounding in the principles of the subject wlil be given and considerable laboratory work will be undertaken, through which a good knowledge of heat treatment, metallographic preparation, microscopic examination and photomicrography may be secured. For further information apply to Prof. H. M. Boylston or S. Z. Krumm, Department of Metallurgy and Mining Engineering, Case School of Applied Science, Cleveland. Telephone—Garfield 2387, evening phone—Eddy 7604 J.

C. U. Kurrash has moved from Chicago to Michigan City, Ind., where he is president of the Triangle Steel Products Co., manufacturers of automotive parts.

On page 80 of the October issue of TRANSACTIONS appeared an announcement of a series of bulletins dealing with fundamentals that influence the quality and cost of heated products. The item neglected to state that the bulletins are published by the W. S. Rockwell Co., 50 Church street, New York, and will be mailed to any interested parties upon request. The company has just issued bulletin No. 239, describing an improved type of forge furnace. The novel features of the furnace consist of means for better application of the heat, protection of the operator, and utilization of waste gases to preheat air and fuel for combustion.

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